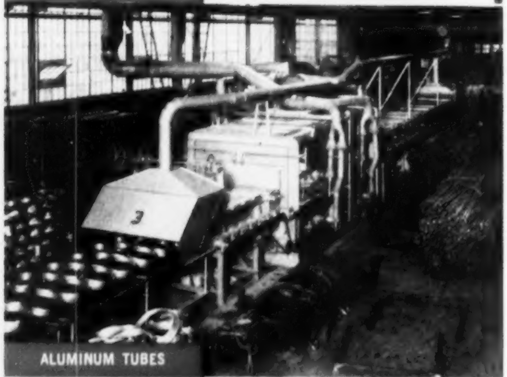
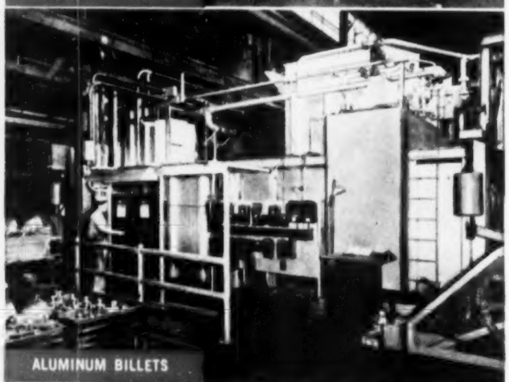
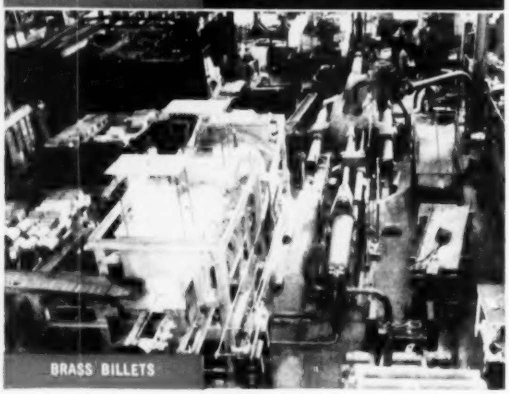
Metal Progress

DECEMBER 1953


BRASS SLABS AND STRIP


ALUMINUM TUBES


ALUMINUM BILLETS


BRASS BILLETS

costs trimmed quality assured

in tailor-made furnaces for non-ferrous metals

Whatever non-ferrous metals you heat treat—in whatever size or shape—'Surface' engineers can tailor furnaces to fit your production needs. Some of the many custom-built 'Surface' furnaces are shown here—others have been used for slab heating, annealing, stress relieving, solution heat treating, ageing, forging, homogenizing, precipitation hardening.

'Surface' furnace engineering is based on years of practical experience, intensive research in metallurgical heating methods, and an almost unlimited variety of furnace and conveyor equipment. 'Surface' engineers have worked with the processors of copper, aluminum, and magnesium alloys as well as precious metals; giving them the "right cut" in costs, increased production, improved quality.
Write today for Literature Group H53-6, showing 'Surface' tailoring for heat treating non-ferrous metals and alloys.

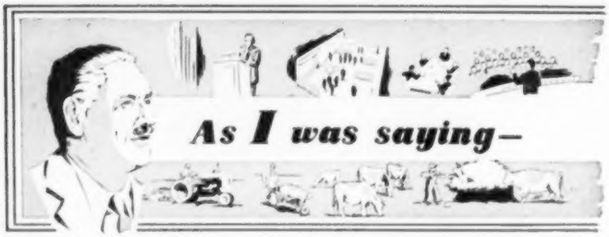
Surface
HEAT TREATING EQUIPMENT

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

ALSO MAKERS OF
Kathabar HUMIDITY CONDITIONING *Janitrol* AUTOMATIC SPACE HEATING

IN THIS ISSUE

•See *Bill's Column on the other side* →



MERRY CHRISTMAS to all of you from all of us!

Will the few of you who read this column kindly refresh your memories about the predictions I made for the Cleveland Metal Congress and Exposition? If you recall them you'll have to admit I missed them all. I said the Congress and Exposition would be great and now it turns out it was colossal.

But I like to underestimate the effects of events. If they don't pan out you don't have to make excuses, and if they exceed expectations—as they did—you can sit back, relax, relieve the inside tension, and live again.

But this exceeding of expectations is really a triumph for you ASMembers. You did a swell job in your technical sessions, your attendance was perfect, and you may well be proud of another feather placed in A.S.M.'s cap.

The Metal Show was the largest industrial exposition ever held in Cleveland. Clocked attendance for the five days totalled 111,061. The number of registered visitors totalled 50,858 (subject to Metal Show Audit).

The greatest headache was the inadequacy of sleeping accommodations for exhibitors, members and customers. Cleveland has 7162 hotel rooms, of which 3500 were allocated to the Housing Bureau, while the remainder was assigned as the hotel management decided. The Bureau, however, was able to place large numbers in surrounding towns, motor courts and private homes, while 246 nights' lodgings were provided free in the Metal Show Dorm in the Public Auditorium. There is one bright thing to look forward to—the Chicago hotels have allocated 6600 rooms for the '54 Metal Show!

Young Engineers' Day on Friday, Oct. 23, exceeded all expectations. Two special trains and countless buses brought 2264 faculty and student engineers from 11 engineering schools to Cleveland. Letters since received vouch for the success of the idea.

Installation of the Exposition had smooth sailing—no labor difficulties. . . . Advance Registration approximated 12,000. . . . The 15-minute coffee period, "another A.S.M. service", was a great success. . . . Free bus transportation was provided from parking grounds and leading hotels to the Exposition. . . . The slogan used on radio announcements "See the Show from one to five" produced more attendance in the afternoon than in the evening. . . . Publicity was the greatest ever given an industrial show in Cleveland . . . hundreds of newspaper inches . . . six TV periods . . . five radio interviews . . . two international TV hook-ups. . . . More technical manpower served in the booths than ever before. . . . The decor received loads of favorable comment. . . . Expressions used were . . . harmonious ensemble . . . glamorous . . . finished . . . beautiful. . . . But most of them said "Fabulous Metal Show" . . . Credit goes to the exhibitors who prepared such wonderful exhibits and who did such a fine job in presenting their products and services.

So let us have a Merry Christmas in '53, a Happy New Year in '54, and make our plans to attend the Midwinter meeting in Boston, March 4 and 5, and the Metal Congress in Chicago, Nov. 1 to 5.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

In this new publication you'll find photos and descriptions of typical installations, cut-away views of the furnaces, description of the control instruments, and complete specifications for various sizes of furnaces, work baskets and trays.

Brand New Tempering Ideas!

As you're reading this ad our entirely new 20-page catalog will be just off press. It tells graphically of some of the remarkable operating results being obtained in hundreds of plants by users of Homo furnaces.

Today, Homo furnaces are being used under practically every kind of operating condition . . . to meet practically every kind of specification . . . on practically every type of work . . . steel, aluminum or glass. There's a wealth of first-hand data available to you.

If your plant does tempering, at any stage of production, we believe you'll be interested in this up-to-date information about the highly versatile Homo method...the five kinds of Homo furnaces and the jobs they're built to do.

We'll send your copy as soon as you request it. Just write our nearest office or 4927 Stenton Ave., Philadelphia 44, Pa. and ask for Catalog TD2-625(1).

LEEDS NORTHRUP
instruments *automatic controls • furnaces*

Jrl Ad TD2-625(1)

Metal Progress is copyrighted, 1953, by American Society for Metals and is published at 404 N. Wesley Ave., Mt. Morris, Ill. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Oct. 21, 1953, at the post office at Mount Morris, Illinois, under the Act of March 3, 1879.

News in 1940—production necessity today

ONLY a few years ago, the science of sensitive, accurate measurement was limited to laboratories. But today, this science is practiced every day in thousands of industrial plants by factory men . . . who don't have to be instrument experts.

Production men wanted to put this science to work, for they had long known that many processes would function at greater efficiency if temperature, pressure and other variables could be more accurately maintained. Although these potential benefits could be proved in the laboratory or in pilot plants, they could seldom be exploited fully in actual production.

Milestone in measurement

One of the main reasons was that existing industrial methods of measurement were not sufficiently accurate, sensitive or fast. Instruments with delicate mechanical balancing systems suffer inherent limitations . . . always require a compromise between sensitivity and ruggedness . . . and can provide only periodic measurements.

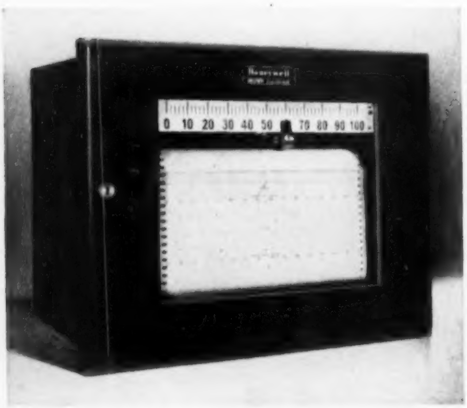
Then, in 1940, the advent of *ElectroniK* instruments swept away these limitations. By adopting an entirely new approach—electronic continuous balancing—these instruments revolutionized the concepts of industrial measurement. They placed laboratory accuracy and sensitivity at the disposal of the production man . . . with all the simplicity and ruggedness demanded by industrial service . . . *plus* speed of response never before economically practical.

Proved by years of performance

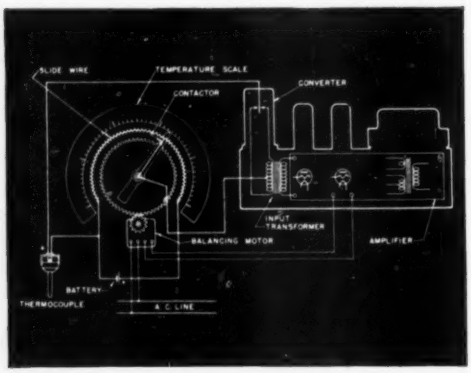
In the past thirteen years, thousands of plants have discovered almost endless applications where the superior performance of these instruments helps to improve operations. The more they learn about *ElectroniK* instruments, the more they call on them for increasingly complex tasks of measurement and automatic control.

Since 1940, the *ElectroniK* family has grown to encompass a host of new indicating, recording and controlling models . . . capable of measuring scores of different process variables . . . equipped with the most advanced types of automatic control. In anticipation of the needs of the future, Honeywell's intensive development program is bringing to readiness even more advanced equipment for tomorrow's process control problems.

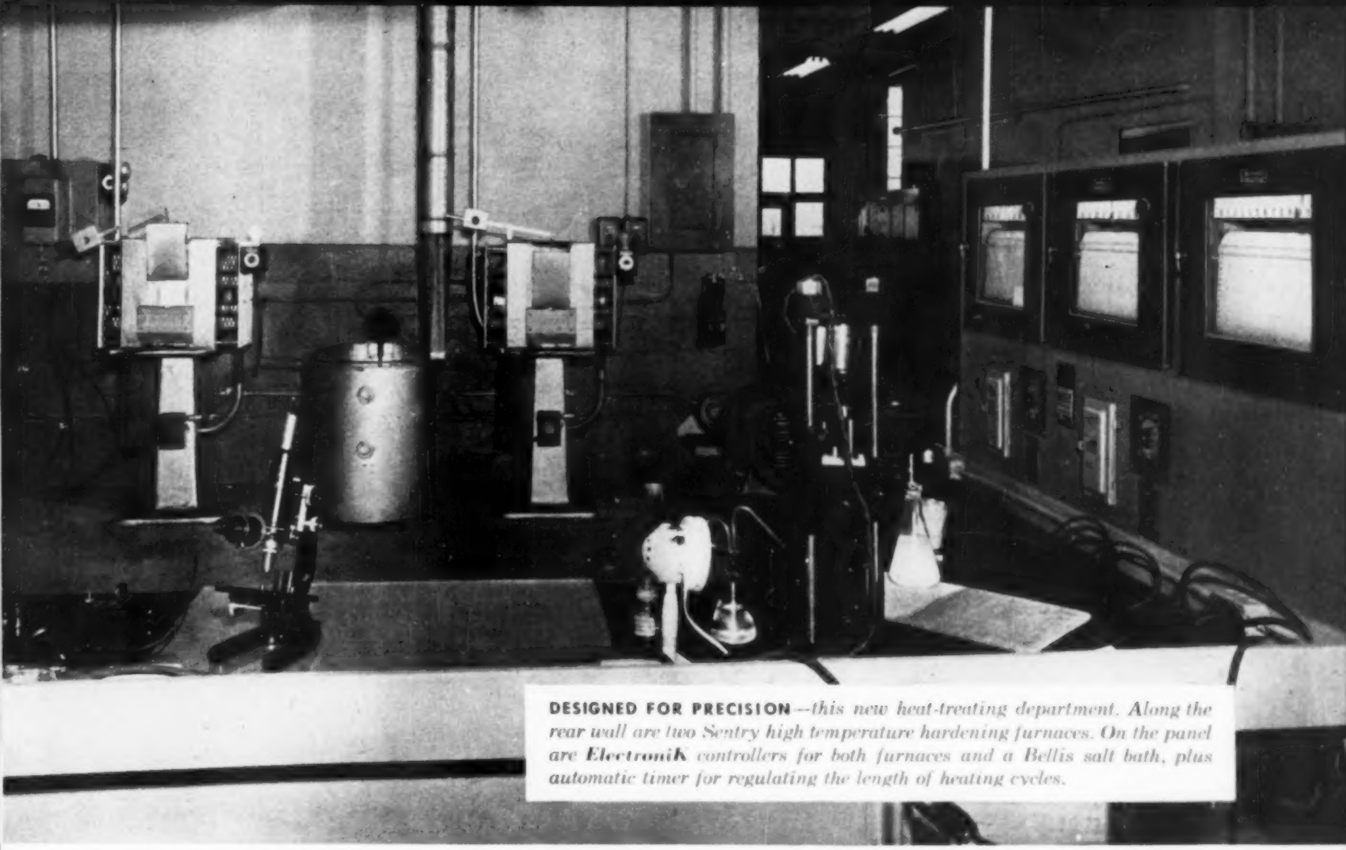
High quality taps in *ElectroniK*-



A FAMILIAR SIGHT *to thousands of production men, scientists and engineers is this strip-chart* ***ElectroniK*** *Recorder, one of a complete family of indicating, recording and controlling instruments.*



POWER PLANT *of* ***ElectroniK*** *instruments amplifies a millionfold the minute electrical signals from thermocouples and other sensing elements.*



DESIGNED FOR PRECISION—*this new heat-treating department. Along the rear wall are two Sentry high temperature hardening furnaces. On the panel are ElectroniK controllers for both furnaces and a Bellis salt bath, plus automatic timer for regulating the length of heating cycles.*

get precise hardening
controlled furnaces

High precision heat-treatment is an essential part of the fine workmanship that goes into ground-thread taps made at the North Attleboro, Mass. plant of the Charles L. Jarvis Co. These taps are made of high speed steel, hardened at precisely controlled temperatures.

The completely new heat-treating department is designed to provide the accurate quality control that the Jarvis Company demands. Hardening is performed in electrically heated furnaces made by the Sentry Co. As many as 76 taps at a time are loaded into each furnace, and heated to the hardening point in the neighborhood of 2300°F. An *ElectroniK* strip chart potentiometer, with on-off control, holds the furnace accurately to one quarter of one per cent of the instrument range.

After hardening, taps are oil-quenched, then tempered in a Bellis electrode salt bath. This bath is also controlled by an *ElectroniK* instrument which maintains temperature constant at 1050°F. The overall result of accurate heat-treating is consistently precise control over hardness . . . a prime consideration for producing fine tools.

Your own heat-treating job, too, can profit by the accuracy and dependability of *ElectroniK* control. Your local Honeywell sales engineer will be glad to discuss your applications . . . and he's as near as your phone.

Minneapolis-Honeywell Regulator Co., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for Catalog 1530, "*ElectroniK* Controllers."

H
HONEYWELL

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

Which of these BASIC MATERIALS will solve *your* processing problems?

Norton ℞ electric furnace products are engineered and prescribed to meet many manufacturing needs

Backed by over 50 years of experience in electrochemical refining, Norton brings you basic materials whose purity and properties are carefully controlled and consistently duplicated.

These Norton electric furnace products differ greatly in composition and characteristics. They are the source of the many Norton *engineered prescriptions* which have proved of immense practical value in widely varying processes.

Moreover, each of them has possibilities for use which are still undiscovered. It will pay you, therefore, to read the following descriptions very carefully. Even this partial list may contain the exact combinations of properties *you* need.

ALUMINUM OXIDE (ALUNDUM*)

Norton is the world's largest producer of this basic material — fused alumina. *Characteristics:* high melting point, about 3700°F; specific gravity, 3.95; good chemical stability, neutral to most chemical reagents; extreme hardness of 2000 Knoop, with great toughness; reasonably high thermal conductivity, 2½ times that of fire clay; high dielectric strength. *Uses:* heavy refractory furnace shapes; pure oxide and sintered refractories; radio tube insulation; porous media for filtration and diffusion; catalyst carriers and fluid catalysts; heat exchange pebbles; wear-resistant parts; laboratory ware.

SILICON CARBIDE (CRYSTOLON*)

Silicon carbide is produced by Norton in large tonnages. *Characteristics:* high melting point, disassociates at about 4175°F; specific gravity, 3.20; extreme hardness of 2500 Knoop, with excellent abrasion and erosion resistance; high thermal conductivity, 7 to 10 times that of fire clay; excellent resistance to thermal shock; maintains great strength to very high temperatures (PCE, 3350°F — cone 37 to 40); unique electrical qualities; relatively low thermal expansion; no inversion on heating; chemically acidic, with good stability. *Uses:* special refractories for boiler furnaces, ceramic kiln furniture, heat treating, hearth plates, high thermal conductivity muffles and retorts; electrical heating elements; lightning arrestors; metallurgical additions; also available in a Norton-patented process for coating graphite — in rocket nozzles and reaction motor parts, etc. — for increased resistance to erosion by high velocity gases.

MAGNESIUM OXIDE (MAGNORITE*)

Fused magnesia of highest purity. *Characteristics:* extremely high melting point, about 5,000°F; specific gravity, 3.58; electrical resistivity, 10^8 ohm cm at 1000°C; chemically basic. *Uses:* linings for metal melting furnaces; high temperature electrical insulation; refractories for handling corrosive caustic materials.

FUSED STABILIZED ZIRCONIA

Norton was the first to develop fused zirconia for practical commercial use. *Characteristics:* high melting point; thermal conductivity in British Units at 2000°F is 6.2 for dense shapes, 4.7 for insulating shapes, 2.8 for insulating grain; high resistance to abrasion and thermal shock; not wet by most molten metals; changes from a fairly good electrical insulator at low temperature to a conductor at 1000°C. *Uses:* refractories for extremely high temperatures; setter plates for titanates; furnace linings for high temperature gaseous chemical reactions; zirconium chemicals; metal melting furnace linings; catalyst carriers; heat exchange pebbles; reaction engine parts including jet and rocket liners.

BORON CARBIDE (NORBIDE*)

The hardest man-made material, an exclusive Norton development of boron carbide. *Characteristics:* high melting point, 4440°F; specific gravity, 2.50; compressive strength, 414,000 psi; bending strength, 44,000 psi; self-bonding, unaffected by all acid and alkali solutions. *Uses:* abrasive for economical replacement of diamond dust in lapping; high purity powder of micron sizings for use as refractory and in "cermet" combinations; neutron absorption in nuclear reactors or particle accelerators; pressure-blast nozzles; wearproof bushings, slides, etc.

In these Higgins type arc furnaces tremendous amounts of electrical energy are utilized by Norton in electrochemically refining crude minerals into basic R refractory materials.

BORON NITRIDE

Refined by Norton to over 98% purity. *Characteristics:* melts or dis-associates at 5400°F; a nonconductor of electricity; weighs only 7 lbs. per cu. ft.; is not oxidized in air at 1200°F. *Uses:* anti-sticking agent for use with molten glass or metal; heat-resistant lubricant; thermal insulator in vacuum or atmosphere furnaces; experimental refractory or crucible material; experimental electrical insulator.

MANY OTHER MATERIALS

Among the high-melting, useful materials made available by Norton are Special Fused Oxides, Refractory Carbides, Refractory Borides, Mixed Borides, Elemental Boron. Research, development and field testing are being conducted on Experimental Borides, Carbides, Nitrides and Silicides. Some of these are in regular industrial use and new uses are being found for others.

AVAILABLE IN MANY STANDARD OR SPECIAL FORMS

Besides supplying these materials in their crude form, more or less as they come from the furnace, Norton has extensive facilities for processing and fabricating — and is ready to work with you in engineering any of these materials to your particular requirements.

GET THIS BASIC MATERIALS BOOKLET

This new Norton Publication, "Basic Materials," contains 22 pages of detailed information, including actual and suggested uses. For your copy, write to NORTON COMPANY, 331 New Bond St., Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

NORTON

R REFRACTORIES

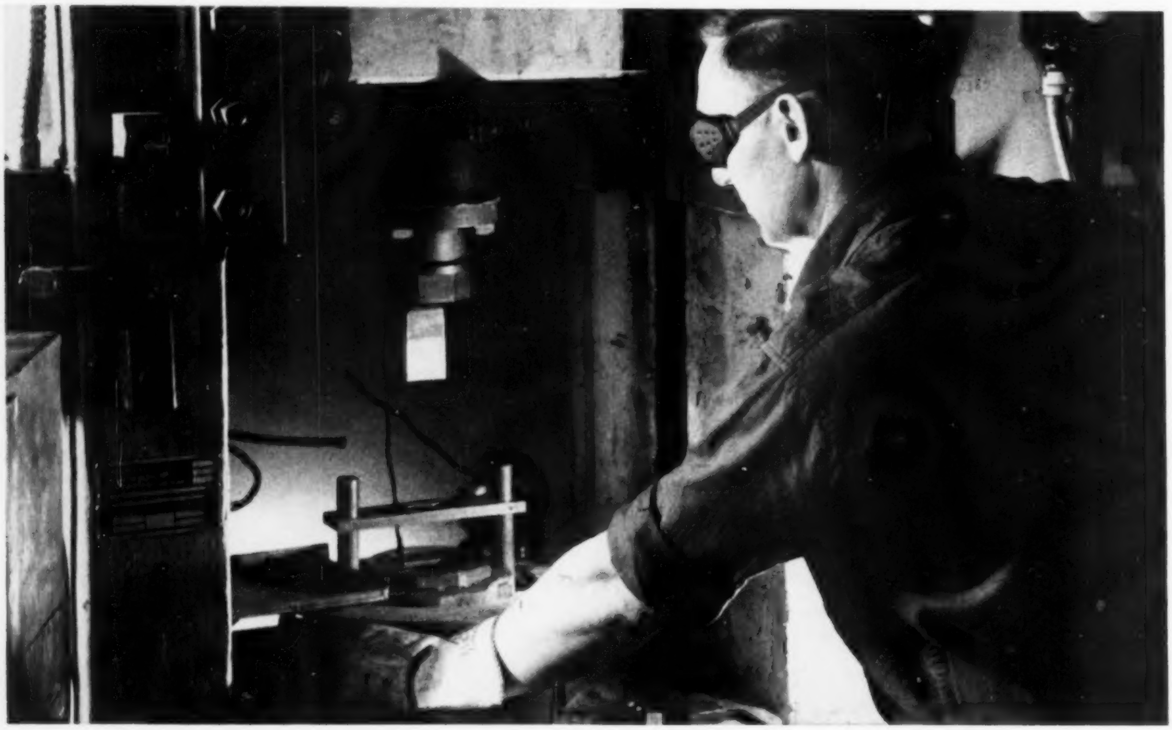
Making better products . . . to make other products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

DOW

IMPACT EXTRUSIONS ARE NOW POSSIBLE IN MAGNESIUM

Savings in tooling and materials handling plus single-step operation assures substantial cost reductions.



The newest technological advancement in the fabrication of *magnesium* is impact extrusion. As a result, it is now possible for more industries than ever before to take full advantage not only of the remarkable qualities of the world's lightest structural metal, but also of the many benefits of impact extrusions.

Here, for example, are just a few of the advantages magnesium impact extrusions provide: (1) Larger parts and more intricate shapes can be impact extruded with less pressure than required for other metals. (2) Impact extrusion die life is extremely good. Many thousands of parts have been made on a single set of dies. (3) Parts can be made in a one-step operation, instead of a sequence of steps required by other methods. (4) More impact extrusions can be made from a pound of magnesium than from a pound of any other metal.

In addition to the advantages of the process, magnesium contributes its own properties which make it exceptionally useful wherever strength and light weight are design factors. It's one-third lighter than aluminum. It's strong and rigid. It has excellent resistance to many organic chemicals and oils. It possesses good electrical conductivity.

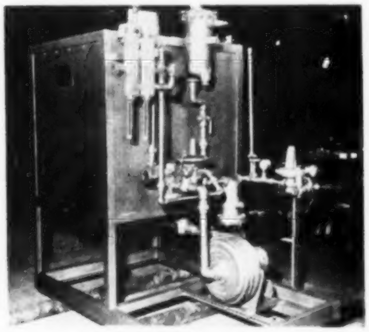
Why not consider magnesium impact extrusions to help reduce your costs . . . to help boost your production . . . to help solve your problems. For more data pertaining to your operations, write to us directly. THE DOW CHEMICAL COMPANY, Magnesium Department, Midland, Michigan.

you can depend on DOW MAGNESIUM DOW

engineering digest OF NEW PRODUCTS

Atmosphere Generator

Ferguson Equipment Corp. has announced a new endothermic type of protective atmosphere generator for protecting metals during heat treatment. This generator features a rectangular alloy retort in the smaller sizes and centrifugally cast alloy retorts in the larger sizes. Radiant tube type elements can be changed during operation. Flow meters and regulators, safety equipment and automatic temperature controls, automatic atmosphere control apparatus and gas enrichment are available.



For further information circle No. 1672 on literature request card on p. 32-B.

Ferro-Beryllium

A master alloy of 5% beryllium in iron, announced by the Beryllium Corp., is designed for making beryllium additions to stainless steels. The alloy has proved successful in the newly developed hardenable 18-8 stainless steel known as V2B. Previous attempts to add beryllium to 18-8 stainless proved impractical when high hardness advantages produced were negated by extreme brittleness and poor machinability. V2B has brought beryllium back into the picture.

For further information circle No. 1673 on literature request card on p. 32-B.

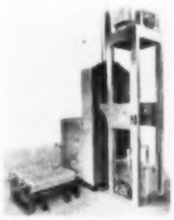
Cutting Oil Base

Dasco, a new soluble base oil, has been especially formulated for metal cutting and grinding by D. A. Stuart Oil Co. It can be used in leaner mixtures than ordinarily recommended for soluble oils. Mixtures usually start at 40 to 1 for milling, drilling, turning, boring, sawing and reaming. Grinding mixtures leaner than 100 to 1 have given good results.

For further information circle No. 1674 on literature request card on p. 32-B.

Metal Remelter

The Nolan Corp. has announced a self-contained unit for remelting of soft metals such as babbitt, solder, tin, zinc, lead and lead alloys. This furnace features compact design, automatic loading, enclosed melting pot, optional means of pouring molten metal and water cooled molds. Pot capacities are available from 600 to 10,000 lb. with optional oil, gas or electrical firing for selectively timed preheat and automatically controlled temperatures up to 850° F. for standard models, and 1000° F. for optional designs.



For further information circle No. 1675 on literature request card on p. 32-B.

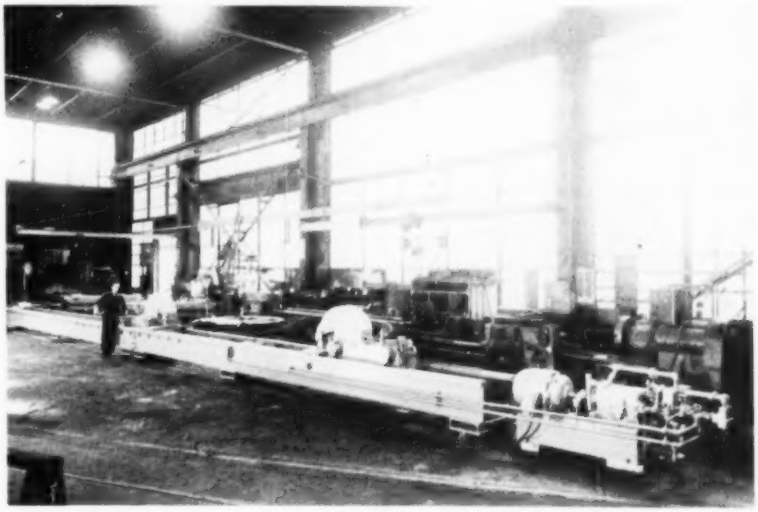
New Abrasive Belt

Minnesota Mining and Manufacturing Co., has announced a new type heavy-coated abrasive belt, combining the polishing characteristics of hand-coated glue and grain set-up wheels and belts. Preliminary field tests have shown that use of the new belt increases production with additional economies in polishing costs, the firm stated. The heavy mineral build-up of the belt opens up under work pres-

Stretcher Leveler

Details on its new stretcher leveler have been issued by the Medart Co. This new machine is completely automatic in operation. The piece to be leveled is placed between the grip jaws by the operator and pushbutton control initiates the clamping of the grip jaws. The machine automatically travels at a high rate of take-up speed and shifts down automatically to a low-speed stretching cycle, and as soon as the preset percentage of stretch is reached, the cycle is automatically stopped, the stretching cylinder unloaded and the jaws opened. The machine can be set from its extreme length of 45 ft. down to 10 ft. in 30 sec. The stretching cylinder is capable of producing a 50-ton stretch continuously, and has a selection of three speeds.

For further information circle No. 1676 on literature request card on p. 32-B.

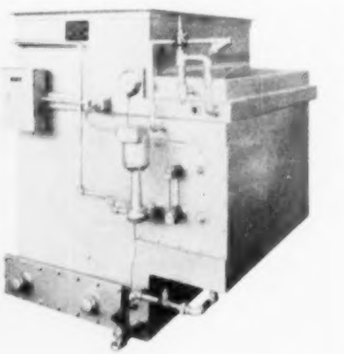


sure, presenting fresh abrasive grain particles to the work piece. The new belt is available in grit 60 and grit 150 aluminum oxide mineral in all standard widths and lengths.

For further information circle No. 1677 on literature request card on p. 32-B.

Vapor Degreaser

Significant improvement of vapor degreasing equipment is claimed by Metalwash Machinery Corp. Its features include: obstruction free tank walls, recessed condensing coils, recessed condensate tray, removable

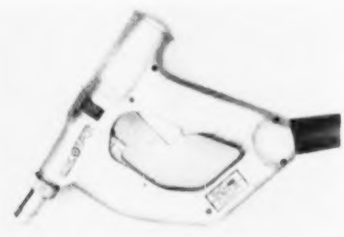


pump chamber and water separator of solid stainless steel, one-end maintenance and demand-type control of water into the condensing system. The recessed multi-tiered condensing coil extends for the full length of the degreaser. Design permits conversion of a straight vapor degreaser to a vapor spray degreaser by the user. Simple installation and maintenance are claimed.

For further information circle No. 1678 on literature request card on p. 32-B.

Spot Welding Gun

The Aircospot gun, a new light weight spot welding gun by Air Reduction, uses a 3/32-in. nonconsumable thoriated tungsten electrode and an inert-gas shield. It makes instantaneous welds on stainless, mild



and alloy steels, without the aid of jigs or fixtures. The unit consists of a hand gun, control panel and all necessary hose and cable assemblies. In order to use this equipment, a standard d-c. power source, either motor-generator set or rectifier type, is required. The gun is water-cooled, and uses helium or argon, or a mixture of the two, for a shield. High frequency is not required. The gun is rated at 250 amp. and welds may be made on sheet metal up to 1/8 in. thick. In most cases, a back-up plate is unnecessary. The operator need only position the top sheet on the piece to which it is to be joined, position the gun and pull the trigger. The operation is completed in approximately one second.

For further information circle No. 1679 on literature request card on p. 32-B.

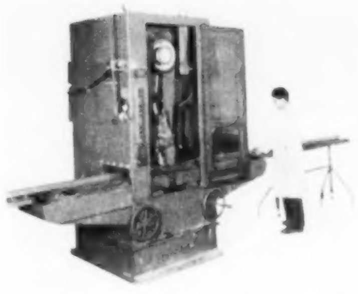
X-Ray Film

A new ultra-fine-grain industrial X-ray film has been developed by Du Pont. Known as Type 510, the film can be used at low voltages (10 to 20 peak kilovolts) to examine low-opacity materials such as aluminum and magnesium. With million-volt X-ray or betatron equipment, it may be used to examine steel up to 3 in. thick. The new film can be used to particular advantage on subjects where very minute detail is desired, since the fine-grain emulsion permits detection of tiny flaws in, for example, spot welding of aluminum sheet.

Type 510 is designed for use without calcium-tungstate intensifying screens.

For further information circle No. 1680 on literature request card on p. 32-B.

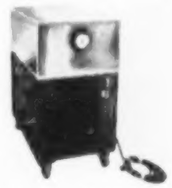
Grinding Aluminum Extrusions



Because aluminum extrusions usually come in 21-ft. lengths, the handling problem for any form of grinding has been difficult and costly. The operation can now be performed at substantial saving with the Curtis Straight-O-Matic machine in conjunction with Carborundum's abrasive cloth belts. This setup, shown in the accompanying photograph, accomplishes the polishing of extruded aluminum so rapidly that it has eliminated the five to six backstand operations formerly needed to meet production requirements. One pass with a 120-grit belt, at a feed speed of 10 to 15 ft. per min., has been found sufficient to remove surface imperfections or scratches from the extrusions. Surfaces obtained with 120 to 400 grit are suitable for anodizing. Oil, greases or water may be used in addition to dry grinding.

For further information circle No. 1681 on literature request card on p. 32-B.

Coolant Cooler

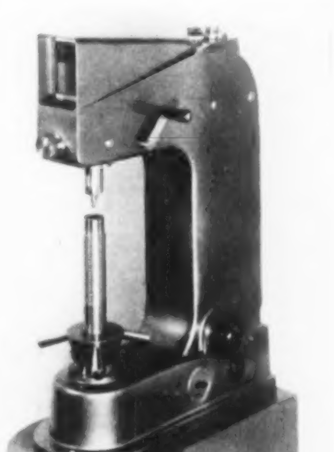


A new coolant cooler for high-production machining operations on hones, lappers, surface grinders, thread grinders and other applications requiring greater control over coolant temperature is announced by Webber Manufacturing Co., Inc. It is designed for normal installation in the coolant line between the pump and the nozzles. Coolers are available in a variety of capacities and sizes for all coolant applications.

For further information circle No. 1682 on literature request card on p. 32-B.

Hardness Testers

The first hand-operated metal hardness testers to provide automatic load changing and magnified optical readings have been announced by the Opplem Co., Inc. The new instruments



are available in both superficial and standard ranges. Automatic changing of loads is done quickly and simply by turning a dial which immediately switches the loads in the interior of the instrument. With this new and exclusive feature, the tester, in re-

cent factory tests, was able to equal and better testing times of a completely automatic instrument. The speed of load application is regulated by a built-in oil damper with an external control. The testers are able to accept samples up to 7½ in. thick.

For further information circle No. 1683 on literature request card on p. 32-B.

Resin Finishes

Two new products have been announced by Parker Rust Proof Co.—Parcolac 101 Black and Parcolac 102 Aluminum, pigmented phenolic resin finishes. The 101 Black produces a deep black color; 102 Aluminum creates an even, light gray finish which looks like a coating of aluminum. Production pieces have withstood 100 hr. in salt spray.

For further information circle No. 1684 on literature request card on p. 32-B.

Largest Radiograph

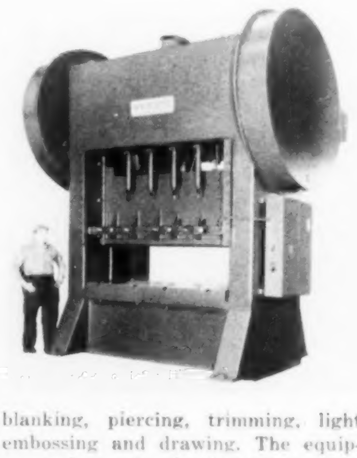
A 40 by 120-in. radiograph, the largest yet produced on a single piece of film, was displayed at the National Metal Congress in Cleveland by Allis-Chalmers Mfg. Co. The giant magnification of two Winchester rifles was accomplished with an Allis-Chalmers 22-mev betatron by using a "magna scanning" technique. Magnification of the rifles was accomplished by direct geometrical enlargement with the film placed 8 ft. from the specimen. The target-to-specimen distance was 4 ft. and the target-to-film distance 12 ft. This resulted in a magnification factor of three. The scanning arc traversed was about 40° which resulted

in the center of the X-ray beam being swept across the full length of the specimen. This technique when employed in industrial radiography has been successful in revealing details of flaws down to 0.001 in.

For further information circle No. 1685 on literature request card on p. 32-B.

Heavy Press

The Cleveland Crane & Engineering Co. announce their entry into the heavy press field with the introduction of a completely new line of presses of 160 tons capacity and up. The new "Wickliffe" presses are intended for uses such as forming,



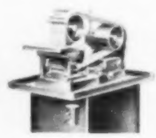
blanking, piercing, trimming, light embossing and drawing. The equipment shown in the illustration is a single-action, straight-side, double-crank mechanical press, rated at 245

tons. Its bed is 48 x 84 in. and is equipped with air cushions.

For further information circle No. 1686 on literature request card on p. 32-B.

Carbide Tool Finisher

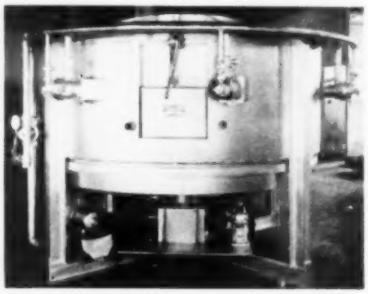
A new method and a new machine for the final finishing of carbide and high speed tools has been perfected by Hammond Machinery Builders. It features a tungsten carbide faced platen, a conventional work table, and abrasive belts in place of diamond wheels. The equipment is for final finishing after rough grinding with a silicon carbide wheel.



For further information circle No. 1687 on literature request card on p. 32-B.

Rotary Hearth Furnace

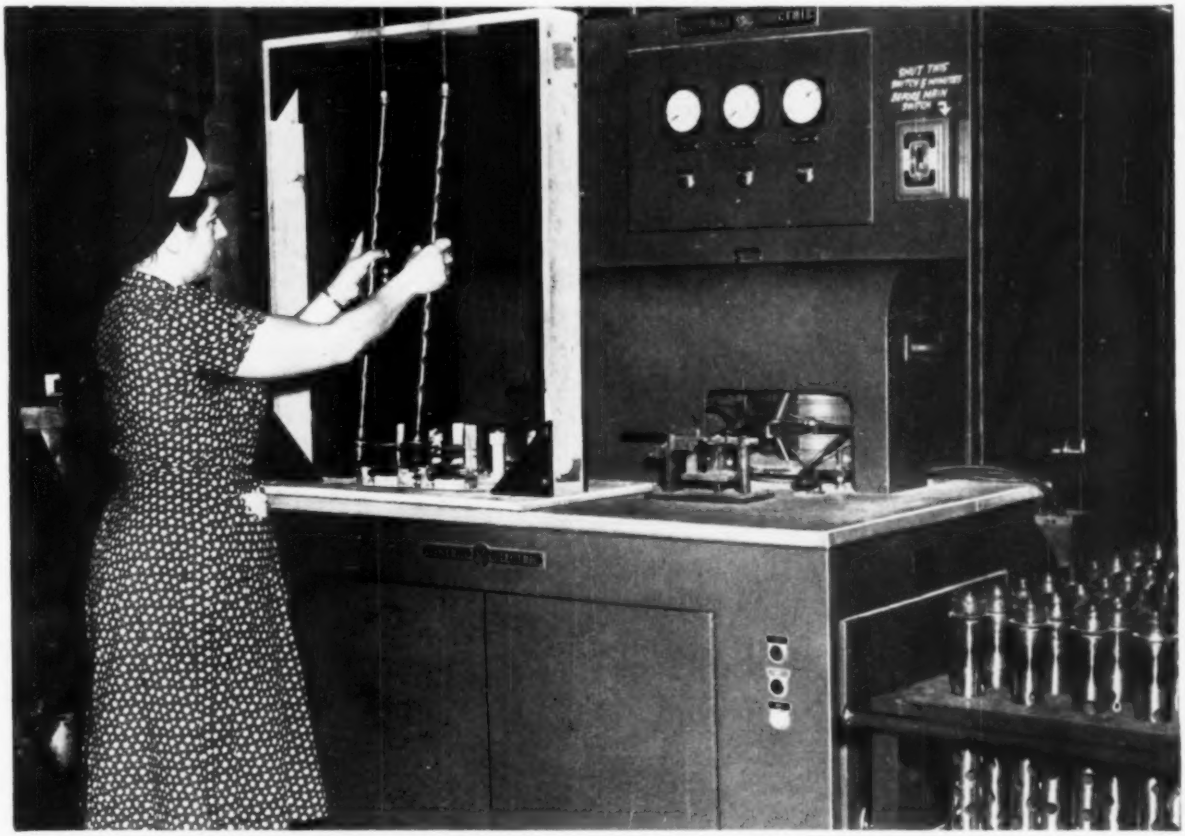
The Waltz rotary hearth furnace shown here has a hearth 7 ft. 6 in. outside diameter with a 30-in. column. Chamber height is 15 in. The center column on the hearth of this furnace forms a doughnut-shaped heating chamber. The burners fire tangentially and against the direction of rotation of the table. The drive mechanism and the blower are mounted on the base of the furnace making the entire furnace self-contained. The top is a separate structure, removable in one piece. The furnace is suited for continuous operations of either forging or heat treating and can be used for temperatures of 1200 to 2300° F.



For further information circle No. 1688 on literature request card on p. 32-B.

Extensometer

A new high-magnification extensometer for gage lengths of 0.4 or 0.5 in. is now available from Tinius Olsen Testing Machine Co. for 1/16 to ⅜ in. diameter specimens. The 0.4-in. gage length model is recommended for standard 0.113-in. diameter specimens. Extremely light in weight, the Type S-9 electric extensometer is used with the Olsen Model



COMPACT G-E HEATERS FOR BRAZING FIT PERFECTLY INTO NEW STRAIGHT-LINE PRODUCTION SETUP AT THE SACO-LOWELL CO.

Rejects Eliminated in Gun-jacket Assembly

Saco-Lowell Company speeds production, cuts costs with G-E Induction Heaters

"In planning our machine-gun production program, we find G-E induction heaters assure us the high-quality brazing necessary to meet strict Ordnance Department requirements," says F. A. Skinner, Chief Engineer, Edwards Plant, Saco-Lowell Shops, Biddeford, Maine.

At Saco-Lowell, brazing rejects are a thing of the past. Only spot checks are necessary for product inspection, because G-E heaters provide a strong, uniform braze time after time. Saco-Lowell saves on operator training too, because use of these semi-automatic G-E heaters is mastered easily in a few hours.

To learn how you can profitably apply induction heat to your metal processing—in brazing, forging, hardening, or annealing—contact your nearest G-E Apparatus Sales representative today. And write now for new, modern-metal-processing bulletin GEA-5889 on furnace and induction brazing to General Electric Company, Section 720-122, Schenectady 5, N. Y.

GENERAL ELECTRIC

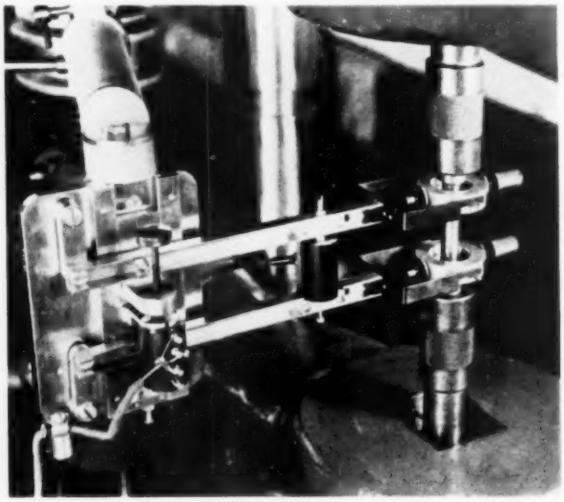
SELECTIVE HEAT produces this clean, strong bond of bearing breach to barrel jacket. Sixty such joints are brazed per hour.

51 electronic recorder for detecting strain under both elastic and plastic tension tests. Easily snapped on to the specimen, this small, sensitive instrument is provided with magnifications of 50, 100 and 200. Overall dimensions of the S-9 are approximately ¾ x ⅞ x 1 in. As the specimen stretches, the activating knife edge on the extensometer moves, which in turn moves the core of the differential transformer. This movement creates an a-c voltage which is amplified to rotate the recorder drum in direct proportion to the strain on the specimen.

For further information circle No. 1689 on card p. 32-B.

Extensometer

A recorder type extensometer designed to produce stress-strain diagrams with high strain magnifications and low magnifications, respectively, below and above the elastic limit of materials has been announced by Baldwin-Lima-Hamilton Corp. Ten strain magnifications

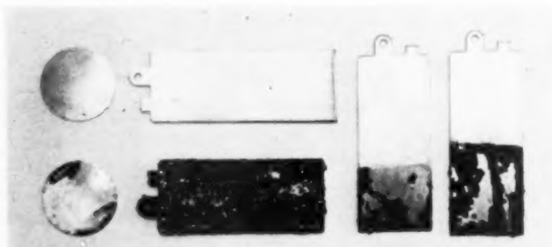


ranging from 5:1 to 200:1 are provided at three positions on extensometer slide and horizontal arms, by the use of extension arms, and by selection of three magnifications. Dual magnification is accomplished by switching. This extensometer can be used on wires, flats, and rounds.

For further information circle No. 1690 on card p. 32-B.

Surface Protection

Results of tests of strippable plastic coatings are shown on these mild steel panels. The surfaces were cleaned, then dipped partially or entirely in a new coating made by Ernst Bischoff Plastics Div. The panels were hung



in test cabinets at 100% humidity, 100° F. for one week. The circular pieces were exposed to outdoor weather for the same time. Dark areas are corrosion product.

For further information circle No. 1691 on card p. 32-B.

special carbide tipped and solid carbide tools. *Super Tool Co.*

1712. Abrasion Tester
Bulletins on durable precision instrument for testing resistance of surfaces to abrasion. *Taber Instrument*

1713. Abrasive Testing
Bulletin No. 6 on methods of running production tests on metal abrasives. *Harrison Abrasive Div.*

1714. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

1715. Adhesives
Bulletin describes polyurethanes and their use in bonding steel to steel, aluminum to aluminum, magnesium to aluminum. *Monsanto Chemical*

1716. Air-Gas Mixer
Bulletin L-700 gives engineering and application data on air-gas proportional mixer. *Eclipse Fuel Eng'g*

1717. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

1718. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

1719. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1720. Alloy Steel
40-page book on heat treated alloy steel plate for maximum abrasion and impact resistance. Details on uses; 12 pp. of technical data. *Jones & Laughlin*

1721. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U.S. Steel*

1722. Alloy Steel
68-page "Aircraft Steels" book includes revised military specifications. Also stock list. *Ryerson*

1723. Aluminum
8-page folder on aluminum roll formed shapes. *Reynolds Metals*

1724. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

1725. Aluminum Strip
20-page book gives technical data on five grades of aluminum strip. *Scovill*

1726. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

1727. Atmosphere Furnace
Booklets H 53-8 on batch-type radiant tube furnaces for gas carburizing, marquenching, dry cyaniding, and other heat-treating operations. *Surface Combustion*

1728. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

1729. Barrel Finishing
Bulletin LCC-53-1 on compounds for barrel finishing, descaling, deburring, finishing, coloring and burnishing. *Lord Chemical Corp.*

1730. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

1731. Beryllium Copper
16-page booklet on applications and properties of beryllium copper. *Beryllium Corp.*

1732. Bimetal Applications
32-page book on application of thermostatic bimetal. Property charts for 30 types. Design formulas. *W. M. Chace*

1733. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

1734. Blackening Stainless
Bulletin on process for blackening stainless steels, cast and malleable irons. *Mitchell-Bradford*

1735. Brass
80-page book on properties and uses of brass forgings, sand castings, rods and machinings. *Mueller Brass*

1736. Brass Foundry
Article discusses sand in the brass foundry. *Lavin*

1737. Brazing
Bulletin 124—on salt bath brazing process—shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies. *Ajax Electric*

1738. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

1739. Brazing Applications
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

1740. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

1741. Bright Annealing
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

1742. Burners
16-page bulletin on selection of gas burners. *Western Products*

1743. Burners
Bulletin 123 on new series of burners for multi-purpose furnaces. *North American Mfg.*

1744. Burners
20-page catalog of oil, gas and combination burners. *Petro*

1745. Carbide Tools
92-page catalog of standard and various

1746. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

1747. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

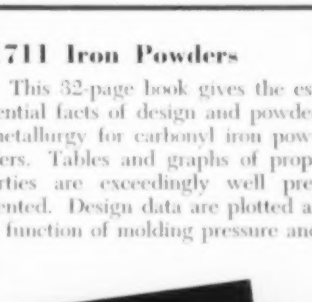
1748. Cemented Carbides
10-page bulletin on use of cemented carbides in wearproofing pulverizing equipment. *Carboloy Dept.*

1749. Cemented Carbides
64-page catalog 52 gives latest information on carbide tooling. Completely illustrated details on all types of cutting tools. Handy tables for grade selection and cutting speeds. *Kennametal*

1750. Centrifugal Castings
62-page book on centrifugally cast iron, steel, gray iron parts. ASTM specifications. *American Cast Iron Pipe*

1711 Iron Powders

This 32-page book gives the essential facts of design and powder metallurgy for carbonyl iron powders. Tables and graphs of properties are exceedingly well presented. Design data are plotted as a function of molding pressure and



amount of binder. Electromagnetic data are given for six types of powder. Pertinent mathematical formulas and a complete bibliography of 105 references are included. The book is printed in three colors, which are used to increase the clarity of data presentation, rather than for "splash". *Antara Chemicals*

1751. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

1752. Chromium Cast Iron
"Abrasion - Resistant High - Chromium Iron" on how to make and use abrasion-resistant iron castings efficiently. *Electro Metallurgical*

1753. Chromium Stainless
Folder on uses of chromium stainless steels; table of analyses and properties. *Lebanon Steel Foundry*

1754. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

1755. Coating Aluminum
Bulletin on anodic coating of high hardness for aluminum alloys. *Anodic*

1756. Coatings, Metal
High-vacuum evaporation of metals set forth in detail in 12-page booklet. *Consolidated Vacuum Corp.*

1757. Combustion
Bulletin AD-607 on oxygen index of combustion processes. *Arnold O. Beckman*

1758. Combustion Control
20-page booklet on combustion of various fuels and portable instruments to measure content of oxygen and combustibles. *Cities Service Oil*

1759. Compressors
12-page data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1760. Contouring
8-page brochure on three-dimensional duplicating facilities for production of airframe sections and dies and molds for metal products. *MPM, Inc.*

1761. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

1762. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

1763. Copper Alloys
64-page book on free-cutting brass, copper and bronze. *Chase Brass*

1764. Core Oils
Bulletin describes core oils, pastes, washes and binders. *Pelron*

1765. Core Ovens
Bulletin 31 on batch-type foundry ovens for ferrous and nonferrous shops. *Despatch*

1766. Corrosion of Copper
28-page booklet B-36 discusses corrosive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass*

1767. Corrosion Resistance
32-page brochure on causes of corrosion and means of combatting them. Choice of materials for condenser tubes. *Revere Copper & Brass*

1768. Corrosion-Proof Cement
12-page bulletin gives corrosion resistance of four types of cement vs. 176 chemical solutions. *Atlas Mineral*

1769. Cut-Off Wheels
36-page revised manual on cut-off machines and abrasive wheels. *Norton Co.*

1770. Cutting Fluids
Cutting and grinding fluid selector for various machining operations. *D. A. Stuart*

1771. Cutting Oil
Folder on sulphurized cutting fluid for a wide range of machining jobs. *Gulf Oil*

1772. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1773. Degreasing
Pamphlet on properties and use of trichlorethylene. *Niagara Alkali*

1774. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

1775. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

1776. Die Castings
Folder on possibilities and advantages of die castings. *Precision Casting Co.*

1777. Die Steel
"Die Steels for Hot Work" helps in selection of best grade for particular jobs. *Vanadium-Alloys Steel*

1778. Die-Casting Machines
Copies of "Lester Press" describe various features of aluminum die casting machines. *Lester-Phoenix, Inc.*

1779. Drawing Compounds
Folder on lubricant for forming and drawing of stainless. *Hangsterfer*

1780. Ductile Iron Castings
12-page bulletin on pearlitic, ferritic and austenitic grades of ductile iron. 12 typical uses. *American Brake Shoe*

1781. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1782. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

1783. Electronic Controllers
16-page Bulletin No. B226 on recording controllers for temperature, pressure, flow, liquid level and humidity. *Bristol*

1784. Electropolisher
Bulletin on theory and practice of electrolytic polishing of metallurgical samples. Description of electropolisher. *Buehler*

1785. Extruded Cylinders
Bulletin on extruded steel cylinders

with smooth surfaces and no taper. *Mullins Mfg.*

1786. Extrusion Presses
8-page bulletin on presses designed for extrusion of aluminum, brass and other nonferrous metals. *Lake Erie Engineering*

1787. Fabrication
46-page book shows metal fabrication and production facilities, products and services. *R. C. Mahon*

1788. Fasteners
80 pages of weights and dimensions of nuts, bolts, screws, washers, rivets. *Triplex Screw Co.*

1789. Finishing
Catalog A-654 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

1790. Finishing
28-page catalog B-9 on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

1791. Finishing Aluminum
Folder and reprint on an electroless surface conversion process for bonding paint to aluminum and protecting the metal. *American Chemical Paint*

1792. Flow Meters
8-page bulletin on flow meter for furnace installations. *Hays Corp.*

1793. Flow Meters
16-page catalog on meters for flow rate measurement of liquids and gases by variable area method. *Fischer & Porter*

1794. Forgeability
112-page book, "Evaluating the Forgeability of Steels". Hot work characteristics in chart form for 94 steels. *Timken*

1795. Forging Manipulators
Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

1796. Forming Dies
Folder on styles of forming dies for stainless heads—in wide range of sizes and gages. *Carlson*

1797. Forming Dies
Data on roller dies for forming tubes and rolled shapes. *American Roller Die*

1798. Forming Jaws
Bulletin on Hydra-Curve jaws with flexible action for sheet forming. *Hufford Machine*

1799. Foundry Coatings
Data on colloidal graphite for mold washes, pattern coatings, core coatings, chill coatings. *Acheson Colloids*

1800. Foundry Ovens
Bulletin 30 on conveyor-type forced convection core ovens. *Despatch*

1801. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1802. Furnace Insulation
Bulletin on ceramic fiber that can give impressive savings compared with high-quality insulating brick. *Refractories Div., Carborundum Co.*

1803. Furnaces
44-page Catalog 112, well illustrated, features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

1804. Furnaces
Reprint on forming and heat treating spring harrow teeth at Mid-West Forge & Mfg. Co. *Flinn & Dreffein*

1805. Furnaces
12-page brochure on car furnaces of special and conventional design. *Jet Combustion*

1806. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric Furnace*

1807. Furnaces, Heat Treating
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1808. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1809. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

1810. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

1811. Galvanizing
Reprint "Modern Hot-Dip Galvanizing" deals with dross formation as a cause of zinc waste. Detailed information on zinc ammonium chloride type of flux. *Hanson-Van Winkle-Munning*

1812. Gas Carburizing
Bulletin on gas carburizing in rotary furnaces. *American Gas Furnace*

1813. Grainal Steel
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

1814. Hard Surfacing
12-page article on selection and evaluation of methods of hardfacing. *Air Reduction Sales*

1815. Hardening Stainless
64-page booklet on Super Scottsonizing

process of hardening stainless steel. *C. U. Scott*

1816. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

1817. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1818. Heat Treating
Loose leaf data sheets on heat treating oils, salts, carburizing compounds. *Park Chemical*

1819. Heat Treating
Brochure on a quick quench aluminum heat treat furnace. *James H. Knapp Co.*

1820. Heat Treating
Bulletin 850 on shaker-hearth furnace for bright carburizing, carbonitriding, hardening. *Hevi Duty Electric*

1821. Heat Treating
56-page "Heat Treating Alloy Steels". *Republic Steel*

1822. Heat Treating
Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam*

1823. Heat Treating Aluminum
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1824. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1825. Heat Treating Stainless
84-page book on heat treating stainless steels, both martensitic and austenitic. *Republic Steel*

1826. Heating Elements
24-page bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div., Carborundum Co.*

1827. High-Temperature Alloys
High temperature work sheet provides valuable suggestions for solving high temperature problems in design and production. *International Nickel*

1828. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 superalloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

1829. Hydrostatic Testing
Bulletin 353 on three machines for hydrostatic testing on a production-line basis. *Steel City Testing Machines*

1830. Impregnation of Castings
Literature on new impregnating equipment for elimination of porosity in ferrous and nonferrous castings. *Metallizing Co. of America*

1831. Indicator
Bulletin 1541 on instrument for the rapid and precise multiple indication of any variable that can be transformed to millivolts. *Minneapolis-Honeywell*

1832. Induction Heat Control
Sheet 83 on miniature radiation-detecting temperature-measuring device for flame hardening and induction heating. *Minneapolis-Honeywell*

1833. Induction Heating
Bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forgings, extrusion and rolling. *Loftus Eng'g*

1834. Induction Heating
Folder on bench-type electronic induction heating generators. *Induction Heating*

1835. Induction Heating
Catalog of heaters, their applications and operation. *Weltronic*

1836. Induction Heating
12-page bulletin 5679 on induction hardening, brazing, annealing at 1000, 3000, and 10,000 cycles. *General Electric*

1837. Induction Heating
Bulletin on low-frequency (60-cycle) induction heating furnace for nonferrous metals. *Magnethermic*

1838. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1839. Induction Heating
"Induction Heating" . . . presents case histories of increased production, reduced space, lower costs. *Westinghouse*

1840. Industrial Furnaces
Book 127 on planning expansion, remodeling or modernization of plant. *Continental Industrial Engineers*

1841. Insulating Brick
Bulletin on fire brick and sil-o-cel insulating brick. *Johns-Manville*

1842. Iron-Nickel Alloys
32-page bulletin on austenitic iron-nickel alloys having special thermal expansion or thermo-elastic characteristics. *International Nickel*

1843. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

1844. Low-Temperature Properties
48-page bibliography of characteristics of steels at low temperature covers 1904 to June 1953. *Inco*

1845. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

1846. Lubricant
New literature on anti-seize molybdenum disulfide lubriçant. *Bel-Ray*

1847. Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1848. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

1849. Machining Costs
12-page "Relation of Machining Time to Material Cost". Comparative machinability costs per ton for eleven steels. *La Salle Steel*

1850. Magnesium Applications
60-page book gives 54 case studies on uses. *Dow Chemical*

1851. Malleable Iron
Reprint 51-B on metallurgy, treatment and heat treated properties of malleable iron. *Surface Combustion*

1852. Meehanite Castings
8-page bulletin on five engineering grades of Meehanite. Hardenability, other properties, uses. *American Brake Shoe*

1853. Metal Cleaners
Bulletin B-8 gives tabular data on 15 metal cleaners. *Apothecaries Hall*

1854. Metal Detector
Catalog on detector for any kind of metal or alloy. *RCA*

1855. Metal Cutting
64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

1856. Metal Finish
Bulletin 531 on silicone-base heat-resistant finish. *Midland Ind. Finishes*

1857. Metallizing
New bulletin on applications of metal-spraying and torch-fusing method of hard surfacing. *Metallizing Engineering*

1858. Metallograph
Metallograph, described in catalog E-240, furnishes four different accurate images of same sample for complete identification with bright field, dark field or polarized light. *Bausch & Lomb*

1859. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Kent Cliff Laboratories*

1860. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

1861. Nitrogen Atmosphere
Bulletin on generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co.*

1862. Nondestructive Testing
Bulletin on latest ultrasonic testing equipment and techniques. *Sperry Prod.*

1863. Nondestructive Testing
Series of bulletins gives data on both ultrasonic and magnetic testing instruments. Illustrated. *J. W. Dice Co.*

1864. Nonferrous Tubing
Bulletin on seamless, brazed and lock-seam tubing in brass and copper. *H & H Tube and Mfg.*

1865. Oil Quenching
Catalog V-1146 on self-contained oil cooling equipment. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

1866. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1867. Openhearths
Brochure on modern openhearth design and construction. *Loftus*

1868. Paint Spraying
Folder on ionic gun and ionic high potential paint spraying equipment. *Scientific Electric*

1869. Peening
Bulletin on use of cut wire shot for peening and cleaning. *Park Chemical*

1870. Periodic Chart
Latest periodic chart of the elements. Green and black. 11 by 14 in., official 1952 data. *General Electric*

1871. Phosphate Coating
12-page "Phosphate Coating Chemicals

and Processes" gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

1872. Phosphating
Pamphlet A-108 on phosphating materials. Phosphating reference chart included. *Turco Products*

1873. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1874. Pipe Standards
48-page booklet on codes and standards for piping and pressure vessels. *Taylor Forge*

1875. Plating
8-page booklet on plating rack designed to make spline section or body of rack a permanent tool. *National Rack*

1876. Plating Solutions
Bulletin 12 on electric heating of pickling and plating solutions. *Pyrosil*

1877. Powder Metallurgy
32-page handbook gives 24 case histories of parts designed or redesigned for powder metal production. Cost comparisons; definitions of terms and list of standards. *New Jersey Zinc*

1878. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1879. Precision Casting
Bulletin on mechanically-operated induction furnace for precision casting. *Ajax Electrothermic*

1880. Precision Casting
44-page Catalog 53 covers every stage of the investment casting process. *Alexander Saunders*

1881. Precision Casting
Bulletin 706 on the Mercast frozen mercury process of investment casting. *Alloy Precision Castings*

1882. Precision Forgings
Data folder on small metal parts forged to within a few thousandths. *Utica Drop Forge*

1883. Presses
Bulletin No. 45 on recommendations for modernization and conversion of old presses. *E. W. Bliss*

1884. Pyrometer Supplies
Buyers' Guide for pyrometer supplies. No. 100-5. *Minneapolis-Honeywell*

1885. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

1886. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton*

1887. Quenching
Data sheet on mixer for agitation of quenching liquids. *Chemineer*

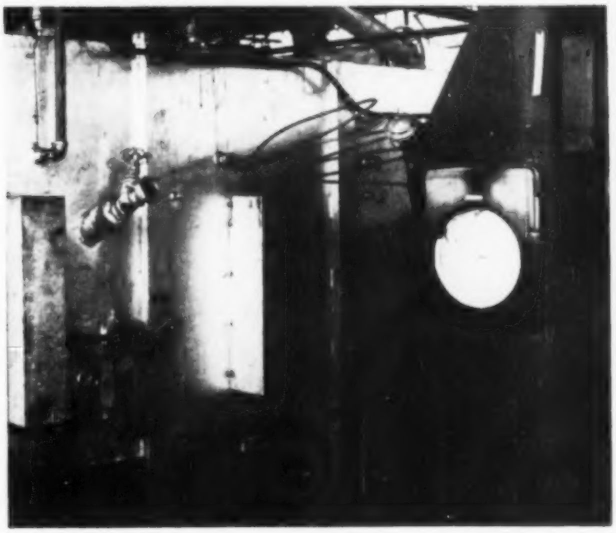
1888. Rare Earths
8-page Progress Report Number 1. "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

1889. Recorder
Bulletin C2-2 on electronic strip chart recorder for temperature, speed, static strain, voltage, amperage. *Wheelco*

1890. Recorder Controllers
48-page ND 46(1) gives specifications, installation pictures of recorders and controllers for temperature, strain, other variables. *Leeds & Northrup*

(*Continued on p. 32-A*)

BETTER REGULATION OF FURNACE GAS GENERATORS



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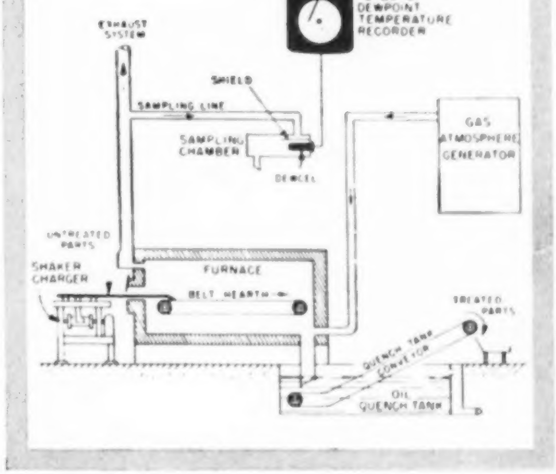

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(Continued from p. 30)

1891. Refractories
Form 1409 on fused stabilized zirconia refractory for furnace linings, metal melting, other uses. *Norton Co.*

1892. Refractory Cement
Data on castable cement for temperatures to 3100° F. *Refractories Div., Carborundum*

1893. Resistance Testing
Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

1894. Resistance Welding
16-page book on steps in making a resistance weld, metals suitable and controls. *General Electric*

1895. Resisters
Data sheets on use of heat sensitive electrical resister for temperature compensation and controlled automation. *Carboloy Dept.*

1896. Rivets
12-page catalog on blind rivets. Applications, specifications, types, descriptions. *Townsend Co.*

1897. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1898. Rust Preventives
12-page bulletin on water-soluble rust-preventive. *Production Specialties*

1899. Salt Bath Descaling
12-page bulletin B-40 describes continuous and batch descaling lines for removing oxide from steel, bronze, copper, stainless and titanium. *Drever*

1900. Salt Baths
28-page book deals with heat treatment, carburizing, bath maintenance, safety precautions. *American Cyanamid*

1901. Sand Control
32-page book on defects and troubles in foundry and how to remedy through sand control. *Claud S. Gordon Co.*

1902. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1903. Screw Thread Inserts
16-page book of design data and specifications on screw thread bushings of helically coiled wire, for aluminum, magnesium, iron, steel. *Heli-Coil Corp.*

1904. Shell Molding
Folder on principal features of shell molding machine. *Shalco*

1905. Shot and Grit
Handy calculator has size data for SAE grades of shot and grit. *Pangborn*

1906. Shotblasting
16-page "Primer on the Use of Shot and Grit." Problems of blast cleaning operations. *Hickman, Williams*

1907. Silver Brazing
Series of eight technical bulletins on silver brazing. Joint strength, design, stress analysis, heat treatment, fluxes. *Handy & Harman*

1908. Sintered Carbides
Catalog of made-to-order tungsten carbide components gives typical shapes and sizes. *Sintercast Corp.*

1909. Soldering Aluminum
6-page folder on use of a noncorrosive flux for soldering aluminum. Data on joint strength and ductility. *Insulation and Wires, Inc.*

1910. Soldering Equipment
8-page brochure on soldering and brazing equipment describes new Mogul soldering gun and shows its applications to production-line soldering and brazing. *Metallizing Co. of America*

1911. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

1912. Spectograph
16-page catalog G2-53 describes grating spectrographs for precision analysis. *Jarrell-Ash*

1913. Spring Alloy
Data on Elgiloy. Industrial uses, properties, special features. *Abrasives Div., Elgin National Watch*

1914. Stainless Castings
Technical data chart gives designations, composition, mechanical and physical properties. *Cooper Alloy Foundry*

1915. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fitting and specialties. *Star Stainless Screw*

1916. Stainless Steel
44-page book gives detailed information on use of stainless steel in the c industries. *Crucible Steel*

1917. Stainless Steel
Slide chart. Set top at a certain cating operation, bottom shows ra each standard grade. On revers heat treating and corrosion data ar *Carpenter Steel*

1918. Stainless Steel
Bulletin gives examples of five stainless steel castings. *Sivyer*

1919. Stamping Tester
Reprint on equipment for dete the drawability of sheet steel. *St Testing*

1920. Standardization
24-page booklet defining stand production and their value as management. *American Standard*

1921. Steam Generators
20-page booklet on the six basi generating units and allied equ *Union Iron Works*

1922. Steel Plate
Bulletin 901 on steel plate f burizing, heat treating and Many uses illustrated. *W. J. Hol*

1923. Steel Tubing
48-page Handbook F-3 on fab and forging steel tubing. Bendin ing, cutting and joining operati scribed. *Ohio Seamless Tube*

1924. Stress Relieving
Bulletin 650 on car-bottom, con type furnace for stress relievin

1925. Stress-Rupture
Data Card 153 gives stress-rupt for nine grades of stainless. *Bal Wilcox*

1926. Subzero Treatmen
12-page bulletin on subzero t of tool steel and increase in tool sulting. *Sub-Zero Products*

1927. Super High Speed
Folder on molybdenum, 8% col speed steel for use at speeds 20 greater than with ordinary hig steel. Heat treatments, protecti ings and uses. *Firth Sterling*

1928. Surface Pyromete
Bulletin 185 on instrument fo accurate readings of surface t tures. *Pyrometer Instrument*

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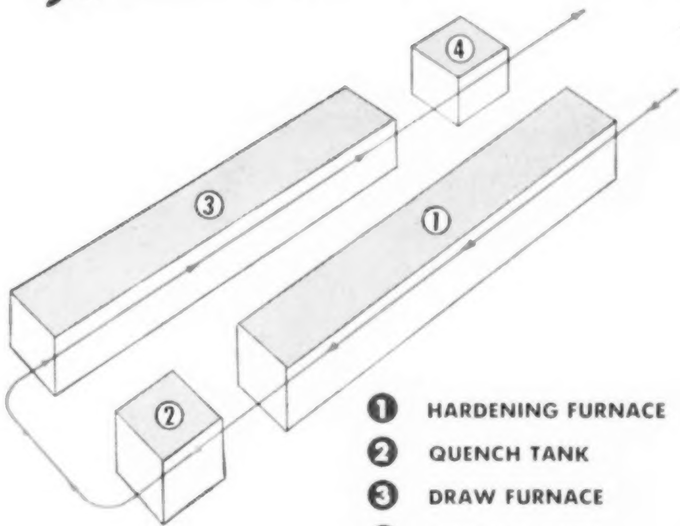

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1929. Surface Treatment
Bulletin No. 51 on methods of treating metal surfaces with peroxygen compounds. *Buffalo Electro-Chemical*

1930. Temperature Control
Bulletin 50H describes thermocouple pyrometer controller. *Thermo Electric*

1931. Tempering
Bulletin 1E 11 on tempering and other applications in liquid baths. *Kemp*

1932. Testing Machines
32-page catalog on hydraulic testing machines. 10 models described; also accessories. *Riehle*

1933. Testing Machines
8-page folder on Amsler machines for tests in tension, compression, torsion, shear, fatigue, bending and ductility. *A. I. Buehler*

1934. Textured Metal
Bulletin describes Armorply, a composite of plywood and textured metal. *U. S. Plywood Corp.*

1935. Thermocouples
36-page Bulletin 235-4 describes various types of thermocouples, extension wire and other accessories. *Foxboro*

1936. Thermocouples
44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. Tabular data on accuracy and limits of couples. *Leeds & Northrup*

1937. Thermometers
16-page bulletin describes dial thermometers for long distance measurement. *Foxboro*

1938. Tin
Monthly newsletter, "Tin News," gives information about prices, supply, demand. *Malayan Tin Bureau*

1939. Titanium
30-page data book on properties of commercially pure and alloy titanium, melting, forging and rolling. 16 charts and micros; 4 hardness conversion curves for titanium. *Republic Steel*

1940. Tool & Die Steels
28-page guide to qualities and sizes available. *Uddeholm*

1941. Tool Heat Treating
Information on "Sure-Wear" process for heat treating high-speed cutting tools. *LR Heat Treating Co.*

1942. Tool Material
28-page booklet on tungsten, chromium, cobalt alloy, its properties and types of tools made from it. *Vascoloy-Ramet*

1943. Tool Steel
Folder on high carbon, high vanadium tungsten base high speed steel. *Latrobe*

1944. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter", analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

1945. Tubing
8-page booklet on stainless, nickel and nickel alloy tubing and small tool specialties. *J. Bishop & Co.*

1946. Tubing
24-page catalog on large diameter, corrosion resistant pipe, tubing and welded fittings. Tolerances, weight tables, grades, alloys and other data. *Stainless Welded Products, Inc.*

1947. Tubing
Bulletin 32 on analyses available, production limits, commercial tolerances, temper designations of seamless and weldrawn tubing. *Superior Tube*

1948. Tungsten Electrodes
Wall chart gives data for inert-gas arc-welding of aluminum, magnesium, stainless steel with pure and thoriated tungsten electrodes. *Sylvania*

1949. Universal Machine
8-page Bulletin 118 on a universal machine tool on which more than 50 different operations can be performed. *Newage International*

1950. Vacuum Finishing
Use of vacuum metallizing in manufacture of plastic and metal parts. *National Research Corp.*

1951. Vacuum Gage
Folder GEC 986 on molecular vacuum gage for measuring pressures without external detectors. *General Electric*

1952. Vacuum Pumps
24-page Bulletin V51 on high-vacuum pumps and accessories. *Kinney Mfg.*

1953. Valves
50-page booklet on valves for the process industries. *Gas Machinery*

1954. Weight Computer
Computer for weights of strips, sheets, bars and plates of various metals and alloys. Also basic specifications for fabrication of pressure vessels. *Continental Copper & Steel Industries*

1955. Weld Strength
Calculator indicates size of weld required for an applied load and weight of a given length of weld. *Lukens Steel*

1956. Welding
3 bulletins on recently developed Filler-arc consumable-electrode gas-shielded welding process. *General Electric*

1957. Welding Alloy Steel
44-page Data Book 4D covers all types of welding of nickel alloy steel. *International Nickel*

1958. Welding Electrodes
Bulletin on electrode selection for welding stainless and alloy steels. *Arcos*

1959. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1960. Weld-Rod Dehydrating
Bulletin on low-hydrogen electrode stabilizer. Specifications of equipment for dehydrating mineral shielding on low-hydrogen electrodes. *Archer*

1961. Wet Blasting Equipment
8-page folder on high velocity, pressure blasting. *Cro-Plate*

1962. Wire Baskets
84-page book on fabricated baskets for dipping and heat treating. *Cambridge Wire Cloth*

1963. X-Ray Analysis
8-page booklet of questions and answers on X-ray analysis. *North American Philips*

1964. X-Ray Diffraction
Analytical applications of X-ray diffraction using direct measurement techniques. *X-Ray Dept., G.E.*

1965. X-Ray Inspection
248-page catalog and supplement on materials used in X-ray inspection. *Picker X-Ray*

1966. Zirconium
26-page booklet gives physical, mechanical and chemical properties, present and potential uses, supply and prices of zirconium. *Zirconium Metals*

December, 1953

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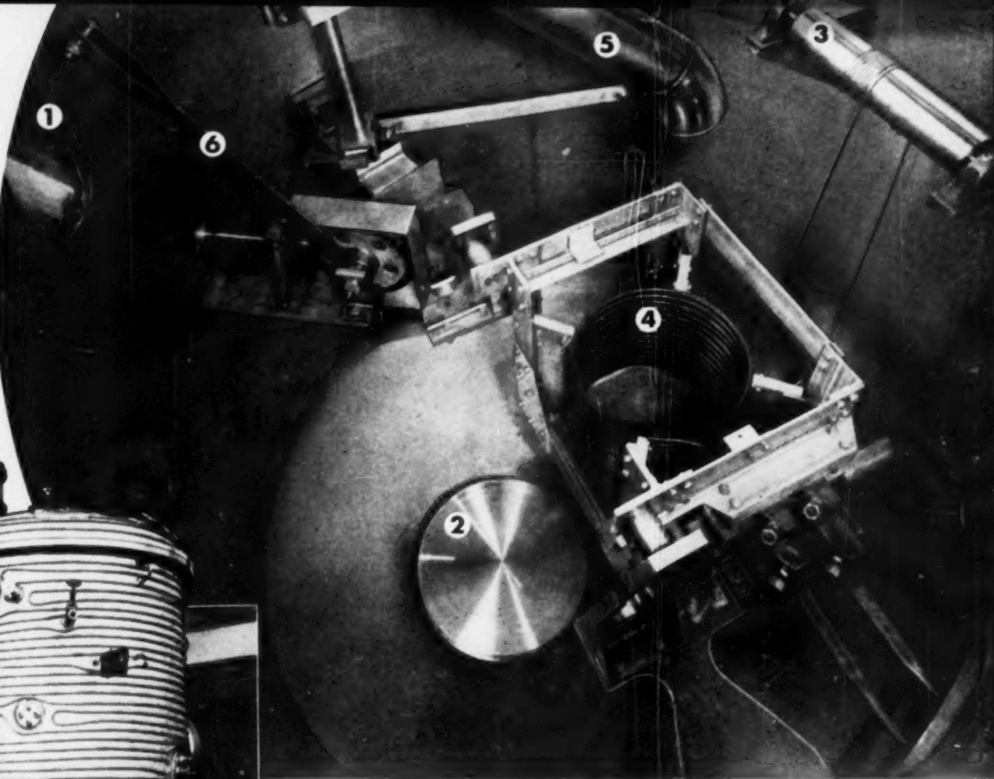

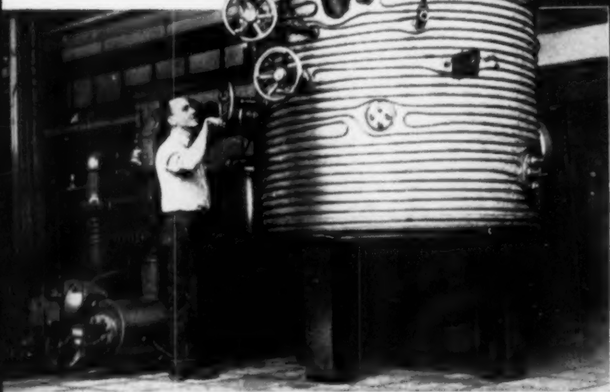

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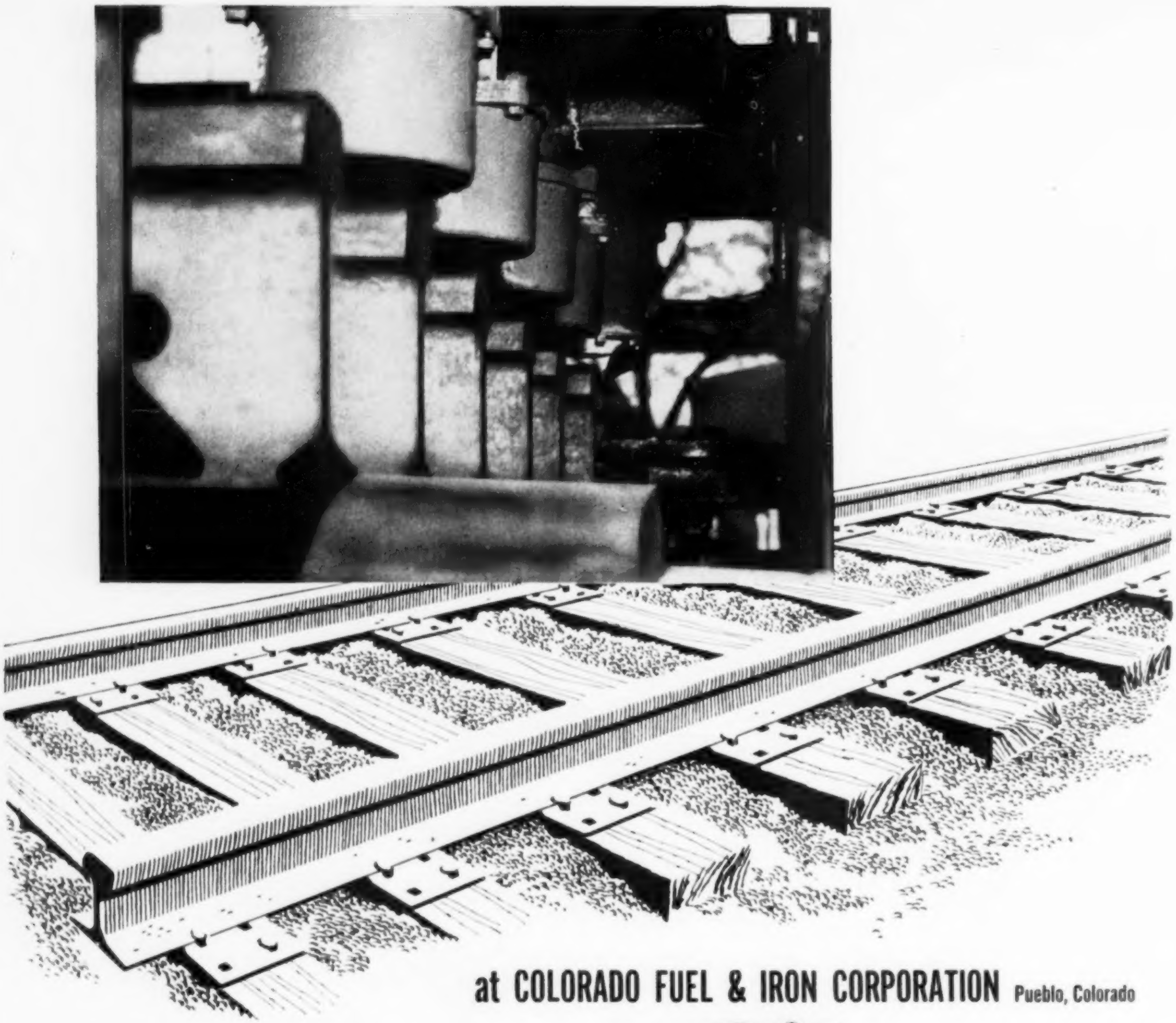

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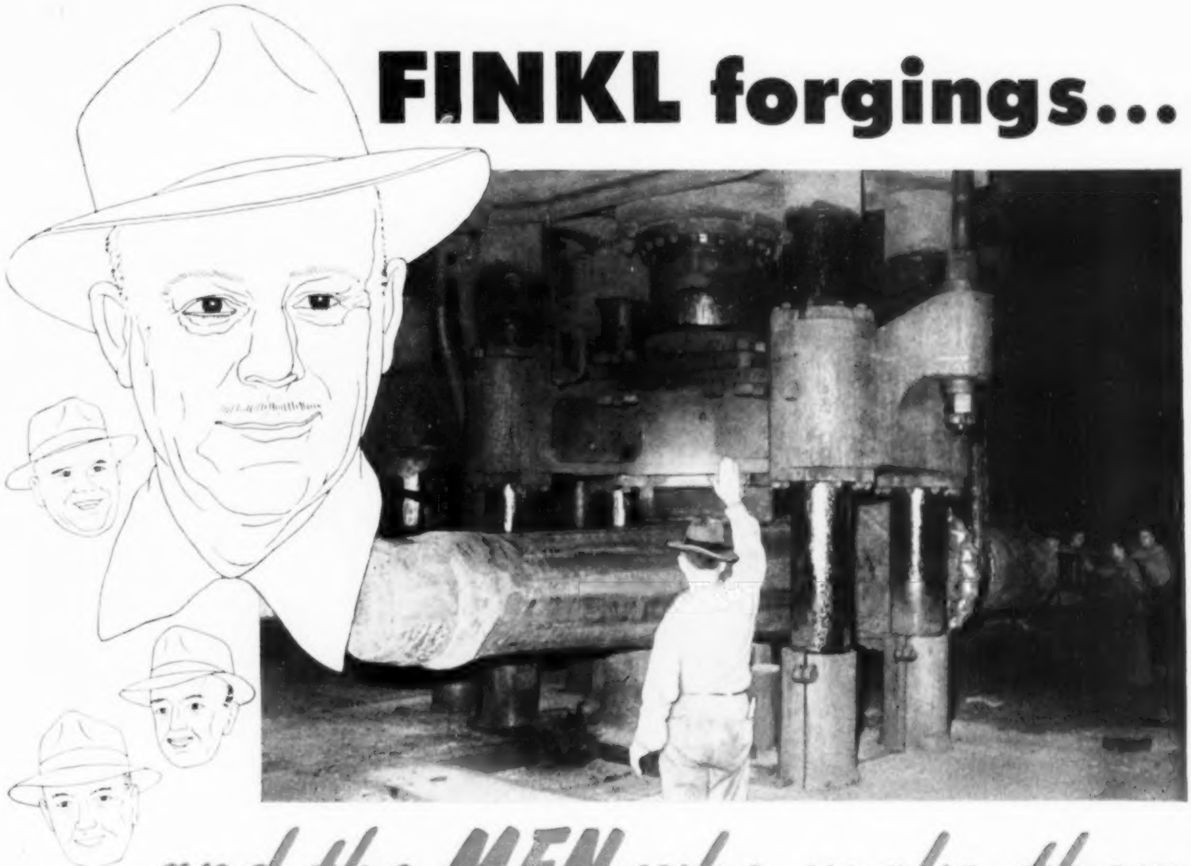

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"YOUR COST PER FINISHED ARTICLE IS THE *TRUE* COST OF YOUR CLEANER"

The case of the "SPOTTED BUMPERS"

Gloom had settled over the "Super's" office. Inspection was rejecting bumper after bumper because of tiny defects marring its gleaming finish.

To make matters worse—ALL the usual test methods failed to disclose the cause of the rejects.

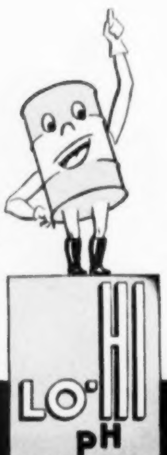
Finally — Northwest was called. A "Cleaning Specialist" rushed to the scene. His methodical check of the cleaning and plating operations revealed nothing amiss.

Retracing his steps, the Northwest "Cleaning Specialist" found "HER". A cute blond—busily racking bumpers—with lovely hands encased in gloves held together with liberal strips of zinc oxide tape.

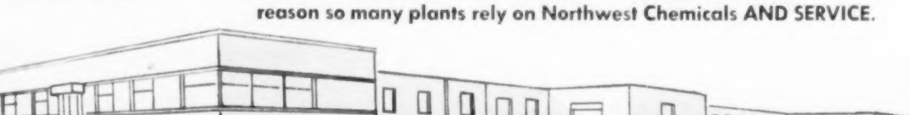
Here was the culprit. Her taped gloves left invisible traces of rubber-like adhesive on the parts after they had been cleaned. A new pair of gloves and production returned to normal.

This little episode illustrates our point that Northwest's "Cleaning Specialists" are not only cleaning experts in a technical sense, but practical production engineers as well.

Any one can give you a cleaning compound that will do a job of sorts, but a Northwest "Cleaning Specialist" will give you the right cleaner to keep your line running smoothly. This is the reason so many plants rely on Northwest Chemicals AND SERVICE.



Got a problem? Let our cleaning experts help you!



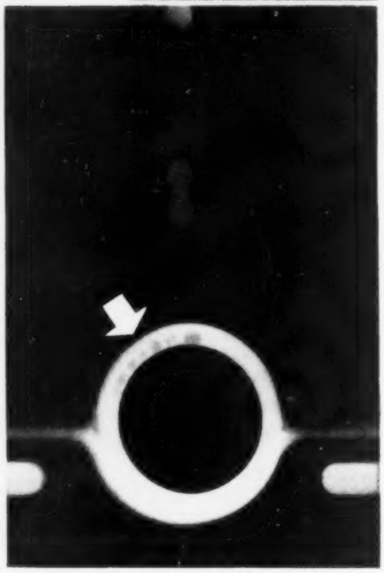
NORTHWEST CHEMICAL CO.
9310 ROSELAWN DETROIT 4, MICH.

pioneers in pH cleaning control *serving you since* '32

Quality, too, may be only skin-deep

1 This apparently sound casting comes from the foundry ready for subsequent machining.

2 Machining uncovers blowholes at critical point — necessitating rejection or repair.



3 Radiograph made before machining would have revealed blowholes, saved time and money.

For fast, non-destructive inspection, use General Electric Industrial X-Ray

Whether you're buying or selling castings, x-ray inspection is a high-speed, low-cost method of insuring unvarying quality. Hidden defects in job lots or on production lines are detected prior to expensive finishing operations.

The above illustrations show why so many leading industries today rely on x-ray for non-destructive inspection. In many plants, x-ray is also used as a development tool — to disclose where savings can be made, designs improved, new techniques developed.

Chances are, there's a place for industrial x-ray in your business. We will be glad to appraise your needs. Or, if you have a specific problem, GE has probably handled a parallel situation. You can benefit from this previous experience by writing X-Ray Department, General Electric Co., Milwaukee 1, Wis., Rm. AS-12.

You can put your confidence in —

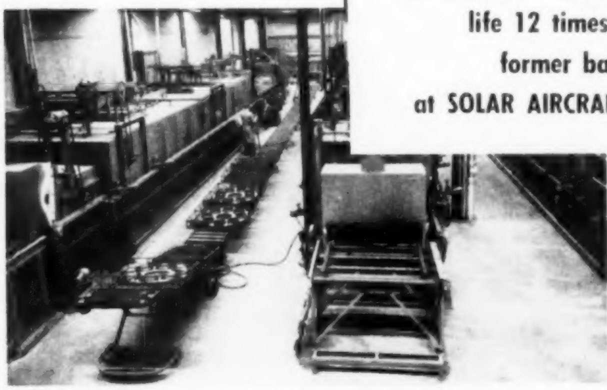
GENERAL ELECTRIC

ROLOCK

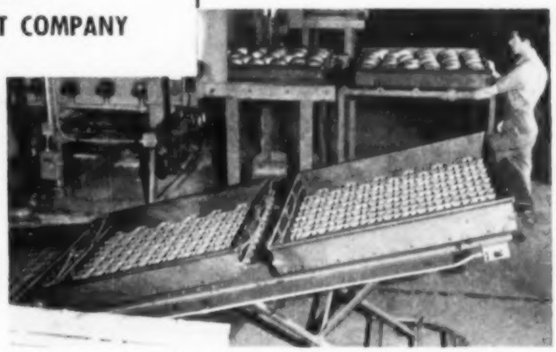
FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

ROLOCK "Serpentine" basket life 12 times that of former baskets at SOLAR AIRCRAFT COMPANY



Jet burner plates leaving gravity belt for travel thru furnace.



Baskets ready for loading, others entering furnace.

Baskets that carry jet engine parts thru these 73½-foot gas atmosphere furnaces for continuous annealing must withstand the tough maximum temperature of 2150° F. That calls for skillful designing of baskets and use of high heat resistant material. Rolock supplied Incoloy baskets incorporating their exclusive "Serpentine" base design, with rolled sheet on two sides and sturdy round rod on the other two . . . all superimposed and integral with the "Serpentine" fully articulated bottom.

Baskets are 42" x 42" x 6" deep O.D. . . . weight 120 lbs., carrying a load of 200-250 lbs. As a replacement for baskets formerly used at Solar's Wakonda plant at Des Moines the new ones have, so far, given 12 times the service life.

Rolock engineers provide practical solutions of your container problem for heat treating or corrosion resistant processing . . . or will cooperate with your own departments for lower hour-cost designs and methods. We like tough problems . . . and welcome yours. Send them in!

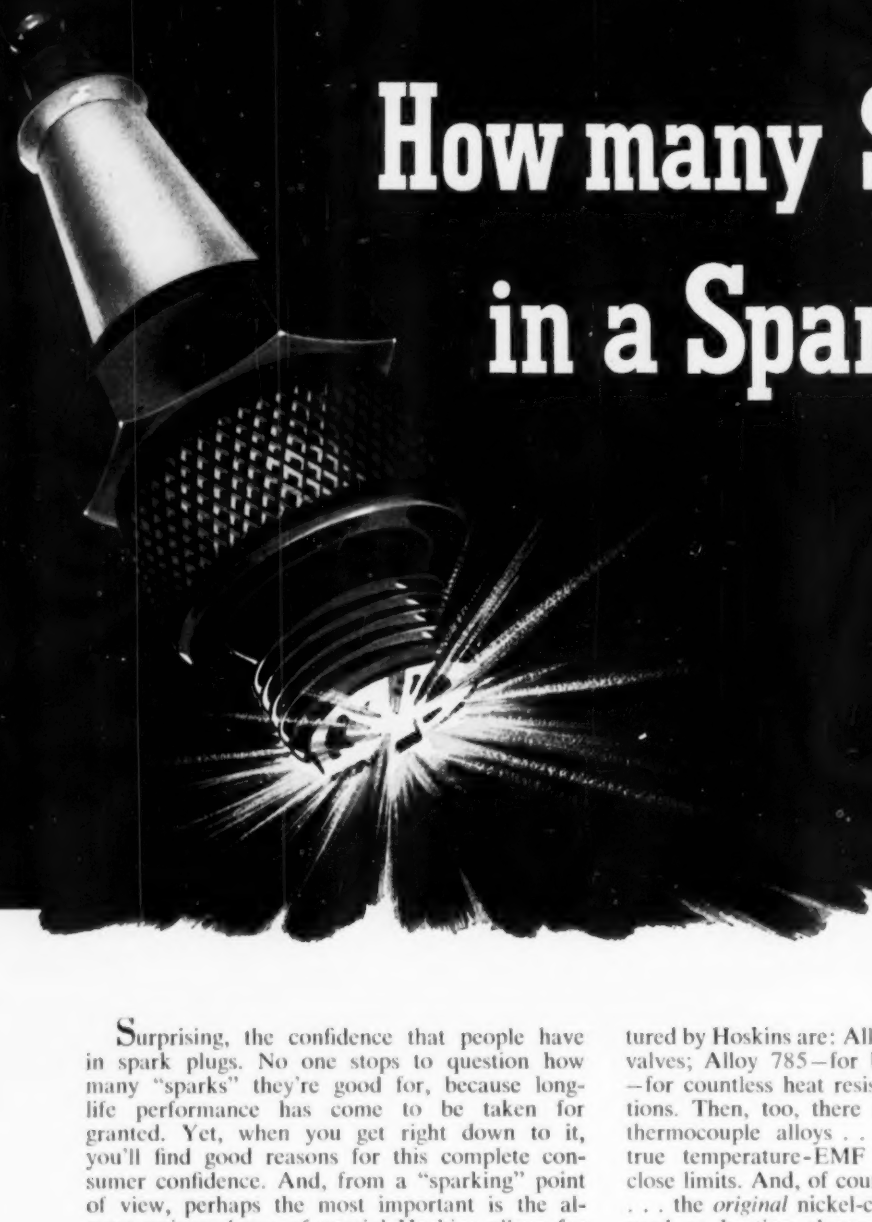
CATALOGS ON REQUEST

Offices in: PHILADELPHIA, CLEVELAND, DETROIT, HOUSTON, CHICAGO, ST. LOUIS, LOS ANGELES, MINNEAPOLIS, PITTSBURGH

ROLOCK INC. · 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

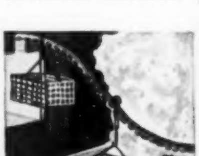
How many SPARKS in a Spark Plug?



Surprising, the confidence that people have in spark plugs. No one stops to question how many "sparks" they're good for, because long-life performance has come to be taken for granted. Yet, when you get right down to it, you'll find good reasons for this complete consumer confidence. And, from a "sparking" point of view, perhaps the most important is the almost universal use of special Hoskins alloys for the vital electrode wires.

Producing the wire that sparks your car to power is a tough and tricky business. It requires special care in the selection of raw materials. Special melting and production techniques. Plus extremely close control over alloy composition and uniformity of quality throughout the entire manufacturing process.

Yet that's exactly the kind of alloy that Hoskins is qualified to produce best. For, among the other quality-controlled alloys developed and manufactured by Hoskins are: Alloy 717—for facing engine valves; Alloy 785—for brazing belts; Alloy 502—for countless heat resistant mechanical applications. Then, too, there are the Chromel-Alumel thermocouple alloys . . . guaranteed to register true temperature-EMF values within specified close limits. And, of course, Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.



Hot stuff for hot jobs! Hoskins Alloy 502 is ideally suited to many mechanical-structural applications.

Heating elements made of Hoskins Chromel deliver full-rated power throughout their long and useful life.

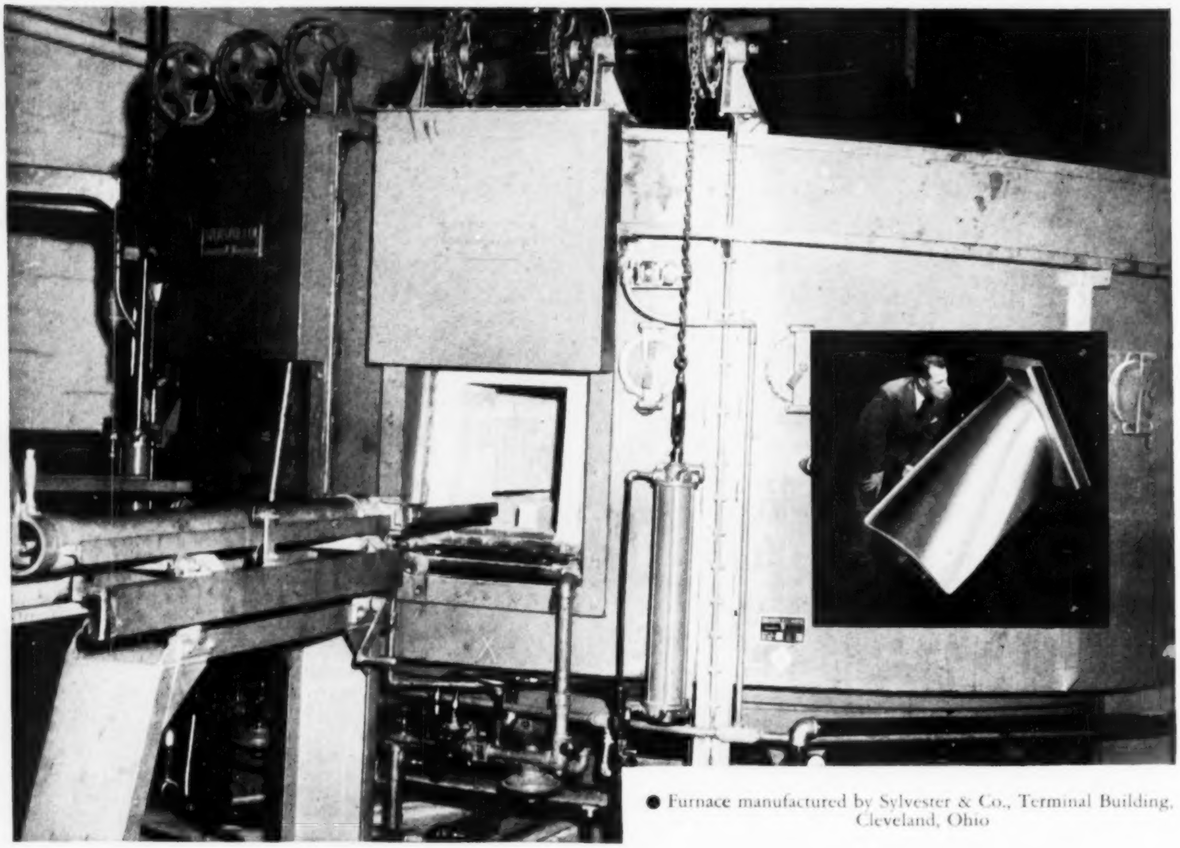
Chromel-Alumel thermocouple alloys accurately measure exhaust temperatures of jet aircraft engines.

Chromel NICKEL CHROMIUM WIRE

HOSKINS

MANUFACTURING COMPANY

4445 LAWTON AVENUE, DETROIT 8, MICHIGAN



● Furnace manufactured by Sylvester & Co., Terminal Building, Cleveland, Ohio

How GLOBAR® Heating Elements can cut your heat treating costs

Look at the ways you reduce rejects and production costs with a modern electric heat treating furnace equipped with GLOBAR® Brand silicon carbide heating elements.

For instance, this Sylvester rotary hearth furnace equipped with forty-eight GLOBAR non-metallic heating elements, is lowering production costs on jet engine turbine blades. This single 250 KW unit can heat 1200 lbs. of steel per hour to 2150°F.

Because loss of metal as scale can often be eliminated by using a protective atmosphere, parts to be hardened are usually machined to exact dimensions . . . and cleaning after soaking is unnecessary, in many cases.

Get these advantages of furnaces using GLOBAR heating elements: pickling and acid disposal eliminated—permitting equipment to be located right in the production area; higher thermal efficiency—which cuts fuel costs; automatic controls—which lower labor costs; fuel handling and processing eliminated, as well as the added cost of furnace construction needed to burn other fuels.

Let us show you how GLOBAR heating elements can best serve you in heat treating—or any other industrial furnace operation. Write today to The Carborundum Company, Dept. MP 87-310, Niagara Falls, N. Y.

GLOBAR® Heating Elements give you

1 **MORE HEAT . . .** per unit area of hearth.

2 **WIDEST RANGE OF TEMPERATURES . . .** up to 2750°F.

3 **SIMPLICITY** of furnace construction.

4 **LESS DOWNTIME . . .** no need to cool or unload during replacement.

GLOBAR® Heating Elements by CARBORUNDUM

REGISTERED TRADE MARK

How to get maximum tube life per dollar: Ask the experts!

This month's report is on: **SICROMO 7**

Suggested as a substitute for steels of the 5.0 per cent chromium type for applications which require increased resistance to corrosion by hot petroleum products.

ONE OF 24 TIMKEN HIGH TEMPERATURE STEELS

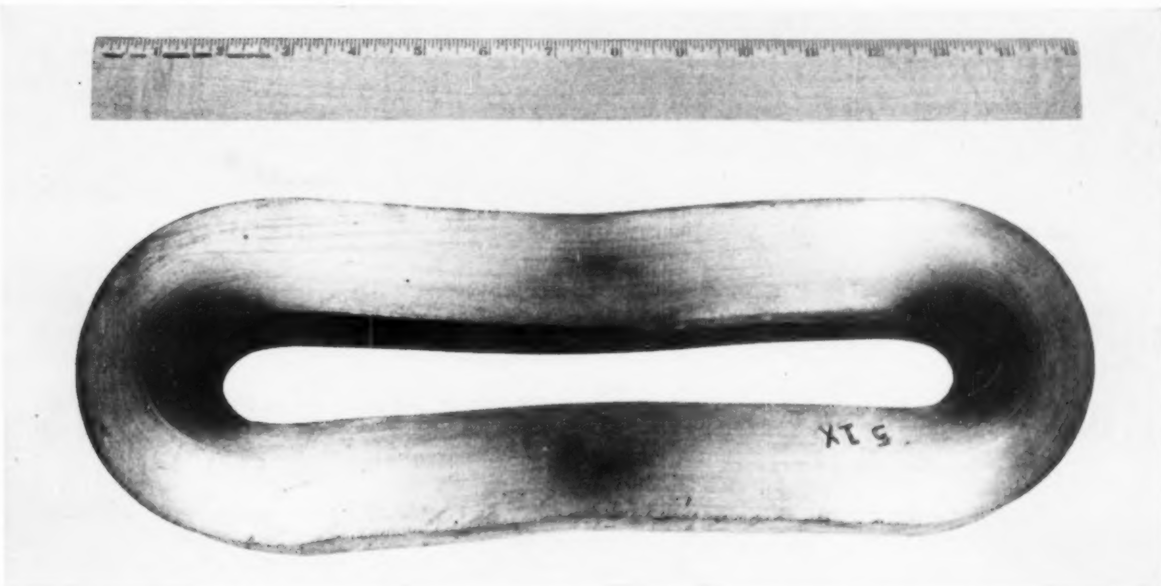
Carbon	Sicromo 2	Sicromo 5S	18-8 Ti
Carbon-Mo.	Sicromo 2½	Sicromo 5MS	16-13-3
DM-2	2½% Cr.-1% Mo.	Sicromo 7	25-20*
Silmo	Sicromo 3	Sicromo 9M	25-12*
DM	4-6% Cr.-Mo.	18-8 Stainless	35-15**
2% Cr.-Mo.	4-6% Cr.-Mo.-Ti.	18-8 Cb	16-25-6**

** Available as seamless tubing on an experimental basis only.*
***Not available as seamless tubing.*

YOUR temperature, pressure, corrosion and oxidation problems may be solved by serveral analyses of high temperature steels. But from the standpoint of maximum tube life per dollar—the best life/cost ratio—there's only *one* analysis that's best for you.

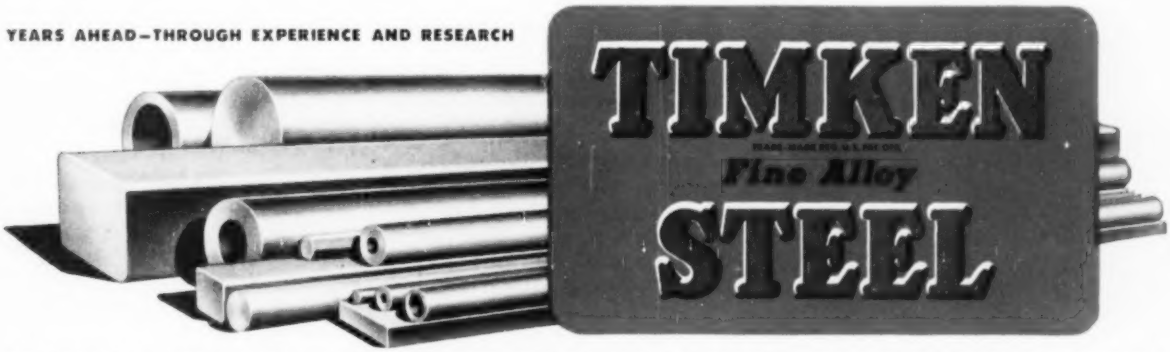
To get that one analysis, go to metallurgists of The Timken Roller Bearing Company. They're recognized authorities on high temperature steels—with more than 20 years of steel research and experience behind them. They'll help you choose the one tube steel analysis that's best for your application from the 24 different analyses at their disposal. And no matter which one you choose, you can be assured of uniform quality because the Timken Company rigidly controls quality from melt shop through final tube inspection.

Let our "RSQ"—Research, Supply, Quality—solve your tube problems. *Ask the experts!* The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".



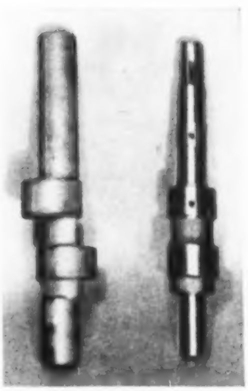
Flattened test of 10½" O.D. by 1.580" wall of 18-8 Cb showing the excellent ductility of large, heavy-wall Timken seamless tubing.

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH



SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

This furnace helps make ice cubes and cool breezes



Raw casting and finished crankshaft of York hermetic compressor. Cast from metal melted in Detroit furnace.

TWO Detroit Rocking Electric Furnaces produce the iron alloys for castings used by York Corporation in their ice-making and air conditioning equipment. The furnace illustrated has an 8000 lb. capacity; the other's capacity is 2000 lbs.

In the York foundry, Detroit Rocking Electric Furnaces were chosen to meet the requirements for high quality heats produced with speed and economy. Rocking action of the furnaces makes full use of heat from the indirect arc, and guarantees a homogeneous melt. Better metal means better castings, fewer rejects, lower cost.

Investigate Detroit Rocking Electric Furnaces for your needs. For ferrous and nonferrous metals. Capacities from 10 to 8000 lbs. Each installation is engineered to fit *your* particular requirement, solve *your* problem.

DETROIT ELECTRIC FURNACE DIVISION

KUHLMAN ELECTRIC COMPANY, BAY CITY, MICHIGAN

Foreign Representatives: in BRAZIL—Equipamentos Industrias, "Eisa" Ltd., Sau Paulo; CHILE, ARGENTINA, PERU and VENEZUELA: M. Castellvi Inc., 150 Broadway, New York 7, N. Y.; MEXICO: Cia Proveedora de Industrias, Atenas 32-13, Apartado 27A3, Mexico 6, D. F., Mexico: EUROPE, ENGLAND: Birlec, Ltd., Birmingham.

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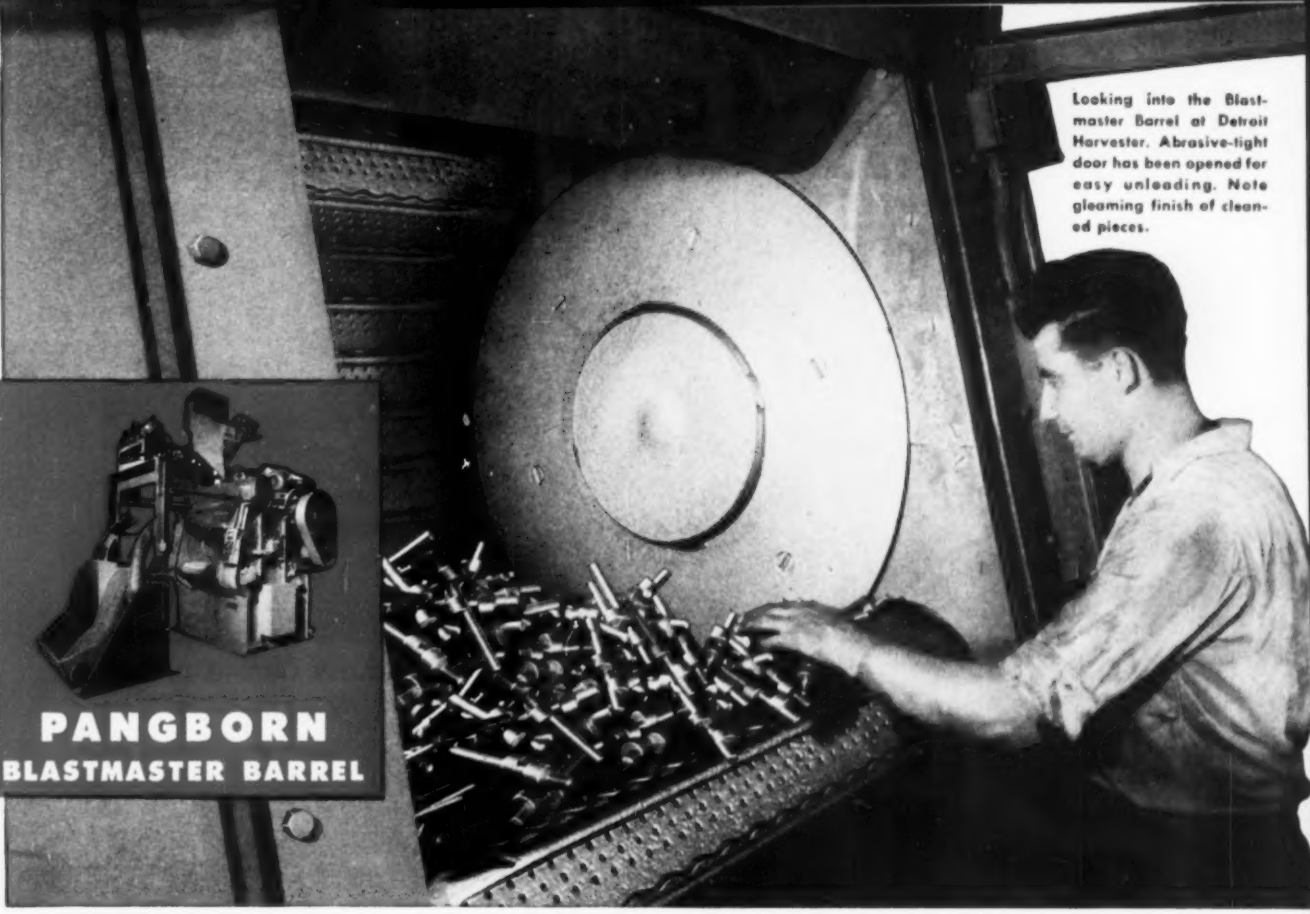


Looking into the Blastmaster Barrel at Detroit Harvester. Abrasive-tight door has been opened for easy unloading. Note gleaming finish of cleaned pieces.

PANGBORN BLASTMASTER BARREL

Cuts Cleaning Time 56%

And gives "finest finish" to the work for Henry and Allen Division of Detroit Harvester Co., Auburn, N. Y.

Formerly, the cleaning operation at Detroit Harvester required 44½ hours a week. Now a Pangborn Blastmaster handles all blast cleaning requirements in only 20 hours a week! So cleaning time has been cut 56%. In addition, labor costs have been reduced and experienced men are released for other work. Superintendent F. C. Palmer reports, *"We are highly pleased with the new Pangborn Barrel. It is very fast and thorough . . . saves money by cutting our blast cleaning job to less than half."*

Quality? Here's what Assistant Foreman Mike Hulik (with the company since 1912) has to say: *"This new Pangborn machine gives us the finest finish I have ever seen."*

The Blastmaster at Detroit Harvester is not an unusual installation. Blastmasters all over the country are winning commendations for fast, cost-cutting, *quality* performance on ferrous, non-ferrous and other metal castings. If *you* are interested in better, cheaper cleaning, it will pay you to investigate the Pangborn Blastmaster Barrel. Available in 4 sizes—3, 6, 12, or 18 cu. ft. capacities. For more details, write for Bulletin 223 to: PANGBORN CORP., 1800 Pangborn Blvd., Hagerstown, Maryland.

102 Sold in 10 months

OVER 28,000 PANGBORN MACHINES SERVING INDUSTRY

Look to Pangborn for the latest developments in Blast Cleaning and Dust Control equipment.

Pangborn

BLAST CLEANS CHEAPER

with the right equipment for every job

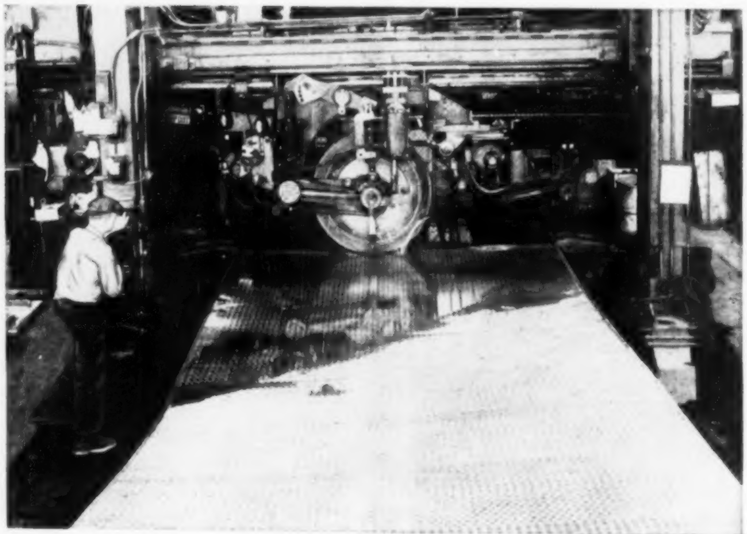
Made to Last in Severe Corrosives

A TOWER OF RESISTANCE

Strips of HASTELLOY alloy C are being arc-welded to this 44-ft. long tower to give it added corrosion resistance. The entire inside surface of the vessel is covered with $\frac{1}{8}$-in. thick sheet.

SEALING OUT CORROSION

This lining of HASTELLOY alloy F will resist acids and alkalies. It is attached to steel by the Smithlining* spotweld process, one of the many ways of attaching HASTELLOY alloys to steel. Use of lined-sheet is an economical means of handling severe corrosives.



HASTELLOY *alloys can help solve your corrosion problems, too. For further information, contact the nearest Haynes Stellite Company office.*

*"Smithlining" distinguishes an exclusive process of the A. O. Smith Corporation, Milwaukee, Wisconsin.

HASTELLOY *alloys*

TRADE-MARK

Nickel-base, corrosion-resistant alloys available as sheet, plate, bar stock, welding rod, welded tubing and pipe, cast pipe and pipe fittings, sand and precision-investment castings.

"Hastelloy" is a registered trade-mark of Union Carbide and Carbon Corporation.

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It's Here! Non-Corrosive Soldering Of Any Type Aluminum Alloy

WIRE SX PRODUCTS

Aluma-Flux

SOLDERING FLUX

A UNIVERSAL FLUX FOR ALL COMMERCIAL METALS USUALLY JOINED BY SOLDERING

HERE is the only flux ever made that assures the *non-corrosive joining* of every type of aluminum alloy regardless of soldering method—mechanical, manual or dip. No corrosive residue remains in most cases, and soldered pieces can be used immediately after the joining operation.

In addition to aluminum, use S-X Aluma-Flux for soldering stainless steel, nickel, brass, copper, bare or galvanized steel, cast iron, and other ferrous alloys. Use it for the quick and easy joining of unlike metals such as brass and aluminum, and for coating copper with tin. There is no other flux like it!

Even when exposed to salt spray, high humidity, alkaline water and other normal corrosion-inducing conditions, aluminum joints made with S-X Aluma-Flux produce no corrosive action. No type of detrimental effect on any soldered joint results from Aluma-Flux.

S-X Aluma-Flux is equally effective when used in molten form, or in powdered form as delivered, whichever is best for the job. Practically any type of solder can be used. And because Aluma-Flux is non-hygroscopic—will not absorb water—it can be stored indefinitely without change of weight or fluxing efficiency.

The success of S-X Aluma-Flux in the soldering of aluminum is due to the action in which the flux initially reduces surface oxides and then immediately deposits a thin layer of plating material on the solder area. Oxidation of the area to be soldered is thus prevented while the plating material serves as an approved base on which to solder. In addition to its soldering efficiency, Aluma-Flux reacts completely during the joining operation so there are no corrosive flux residues to lower corrosion resistance of the finished joint.

Manufactured By
ESSEX WIRE CORPORATION
Ft. Wayne, Ind.

Write For Test Sample & Details

Aluma-Flux Is Ready For Immediate Shipment In Convenient Size Metal Containers

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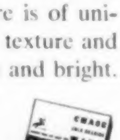
CHASE WIRE can help keep your production costs down

You cut down rejects when you use Chase Brass and Copper Alloy Wire.

Chase mills inspect every coil of wire produced. No scratches, no slivers, spills, or laps! Chase wire is of uniform temper and grain size, uniform in surface texture and color, accurate in gauge. It comes to you clean and bright.

Chase wire is available in a wide variety of alloys, shapes, sizes and tempers.

Write today for free folder "Chase Cold-Heading Extruded Brass and Copper Alloy Wire."



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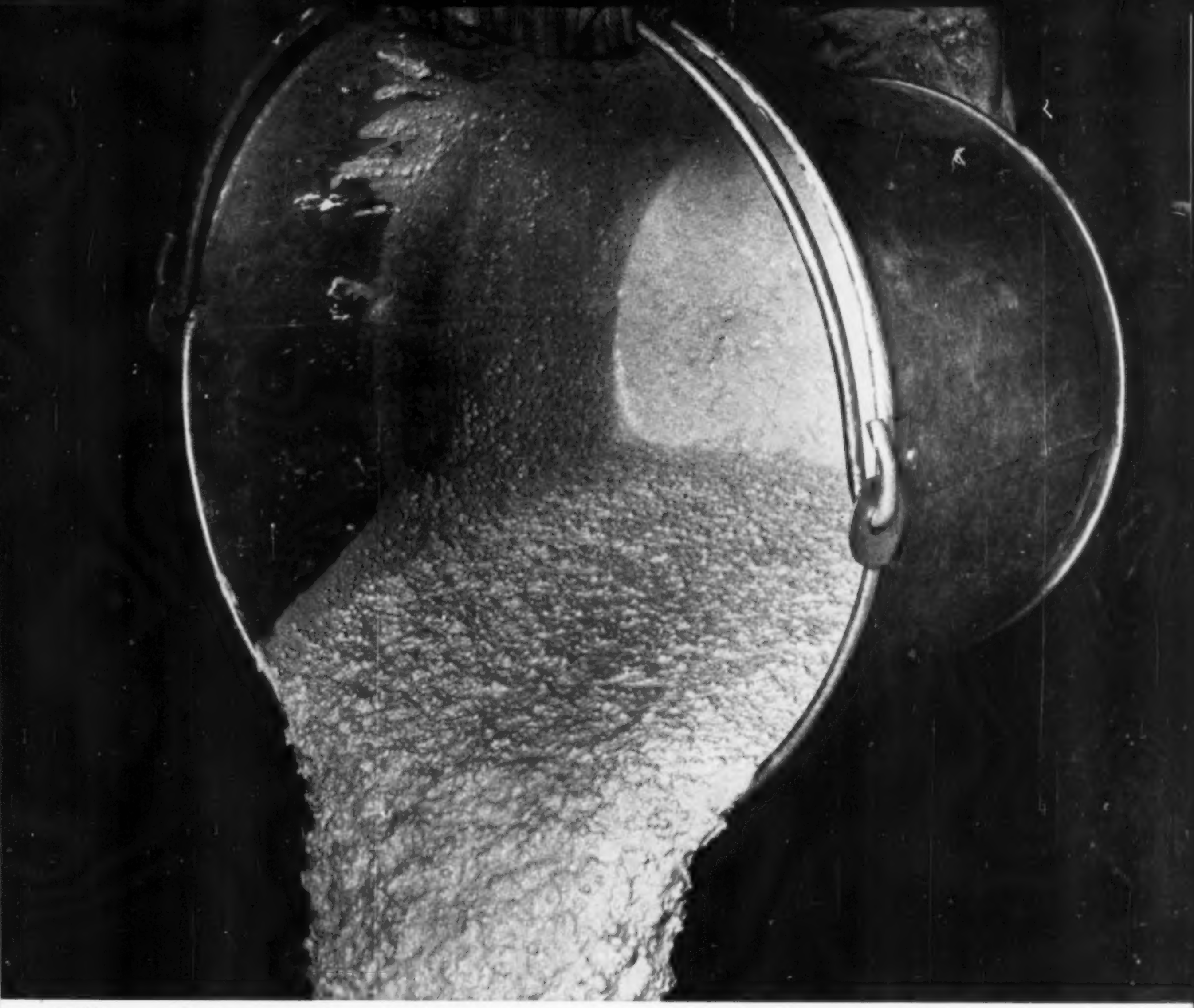

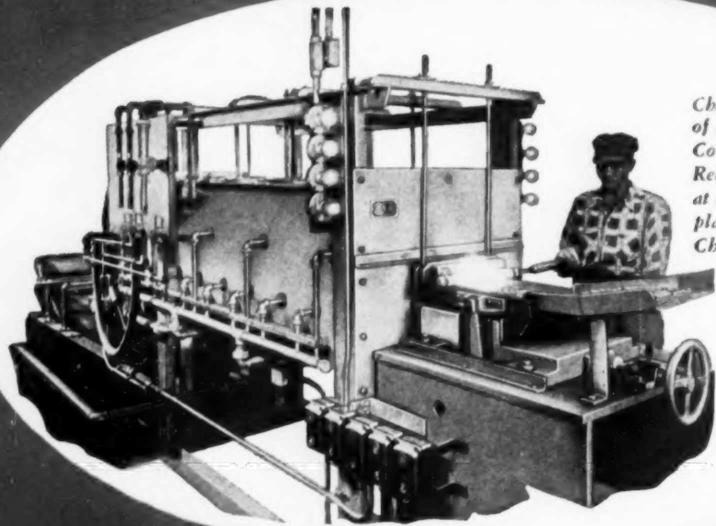

Charging end of the No. 166 Continuous Reciprocating Furnace at the Bellwood, Ill., plant of Chicago Screw Company. The furnace, made by American Gas Furnace Co., is equipped with a cast Chromax muffle.

10,000 HOURS FROM D-H CAST MUFFLE

in shaker hearth furnace

CHICAGO SCREW COMPANY runs this Reciprocating Furnace 24 hours a day, at temperatures from 1550°F. to 1650°F., in an atmosphere of ammonia and carburizing gases, for case-hardening their high quality screws and other threaded fasteners.

In addition to the mechanical stress (up to 60 reciprocating movements per minute) the furnace muffle has to stand considerable thermal shock—for the top of the muffle is hot, while the bottom is continually quenched by cold work pouring in at the rate of 200 lbs. an hour. Under these severe operating conditions it's mighty good news to Chicago Screw that the replacement rate on their muffles is so low. They give full credit to Chromax, the alloy which combines great strength with resistance to high temperatures—also to strict observance of the furnace manufacturer's instructions.

For over 35 years, we have been helping manufacturers meet their heat-treating requirements, to speed operations, maintain quality standards, and cut costs. In most applications Nichrome gives an even lower heat-hour cost than Chromax. But when defense restrictions make Nichrome impossible to obtain, Chromax does a highly economical job, as it did here. Let us know your specific needs; we will be glad to make recommendations and serve you to the best of our ability.

Nichrome*, Chromax*, Cimet* are manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

*T. M. Reg. U. S. Pat. Off.

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

MAKERS OF WORLD-FAMOUS NICHROME AND OVER 80 ALLOYS FOR THE ELECTRICAL, ELECTRONIC, AND HEAT-TREATING FIELDS

Metal Progress ...... December 1953 Vol. 64, No. 6

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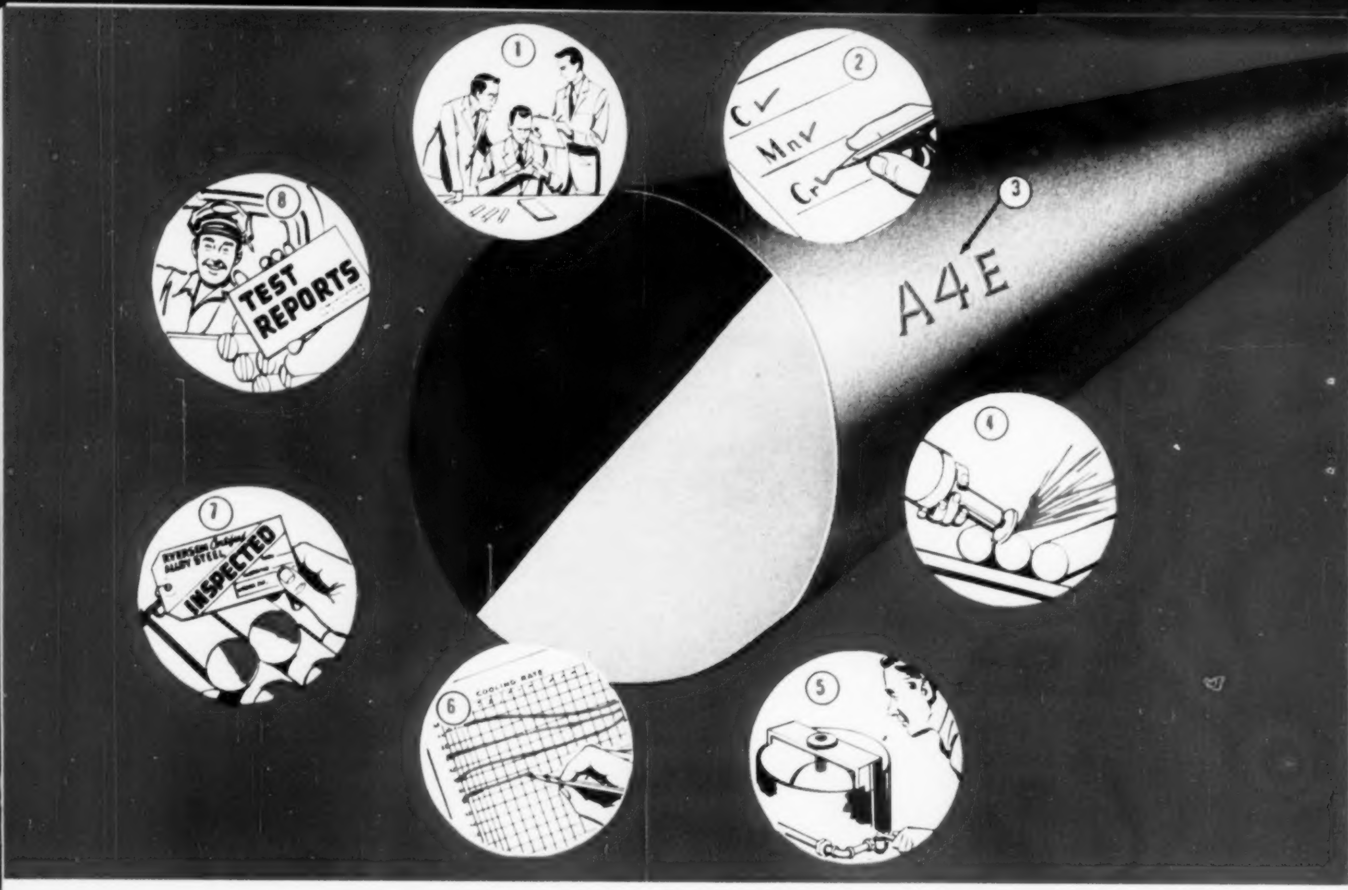
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By WALTHER L. HAVEKOTTE
Chief Engineer, High-Temperature Materials
Firth Sterling Inc., Pittsburgh

Super Refractories for Use in Jet Engines

One of the problems associated with the jet engine is the urgent need for materials that will withstand higher temperatures than any of the materials now in use. There is little hope of obtaining a substantial improvement in the service life of the present alloys. The demand for such materials has led to numerous investigations on the combinations of metals and ceramics known as "cermets". Cermets have high strength-to-weight ratios and, for the most part, the constituents are easily obtained. The titanium-carbide-base cermets are being considered for jet-engine applications, especially for use as nozzle vanes. They possess high strength and resistance to oxidation at elevated temperatures. Their high thermal conductivity is valuable in dissipating heat and contributing to good thermal shock resistance. The biggest obstacle they must overcome is their poor resistance to impact.

Two years ago, Firth Sterling made a study of the refractory materials made in the United States, England and Europe to learn where they could best fit into the high-temperature picture. As a result of this study, they obtained exclusive United States licenses to prepare and market all types of titanium-carbide-base cermets produced by Hard Metal Tools, Ltd., Coventry, England, and by Metallwerk Plansee, Reutte, Austria. This paper deals with an evaluation of some of these cermets as part of a program for further improvement.

Test specimens were fabricated according to the following procedure: The 325-mesh titanium carbide and metal powders were ball milled together in steel mills using tungsten carbide balls and an inert organic liquid carrier. The powders were dried, mixed with paraffin, and pressed at room temperature. The billets were given a low-temperature sinter—1500 to 1800° F., depending upon the hardness desired—and shaped to the proper dimensions, keeping in mind that a shrinkage of approximately 20% occurs during the final sintering operation. The half-sintered specimens had to be handled very carefully because they were very fragile and only chalk hard. The specimens were then fully sintered in a vacuum furnace at a temperature above 2000° F., depending upon the amount of binder, and at a pressure of a few microns. Bodies were finish ground to shape using diamond abrasive wheels.

The chemical analyses and some mechanical properties of these cermets are shown in Table I. The titanium carbide content decreases from 63 to 43% as the amount of binder (Ni plus Co

Table I—Chemical Analyses and Mechanical Properties of TiC Cermets

	Chemical Analyses, %							
Grade	TiC	Ni	Co	Cr	Cr_3C_2	Density G. per cc.	Rockwell Hardness	Modulus of Rupture, Psi
FS-2	63.0	29.6	—	7.4	—	6.00	A-87.2	175,000
FS-5	63.0	—	25.9*	11.1	—	6.15	A-89.5	158,000
FS-8	63.0	22.2	7.4	7.4	—	6.05	A-87.5	162,000
FS-9	50.0	30.0	10.0	10.0	—	6.40	A-82.5	170,000
FS-26	54.3	40.0	—	—	5.7	6.25	A-85.0	165,000
FS-27	42.9	50.0	—	—	7.1	6.55	A-81.0	180,000

TiC Cermets

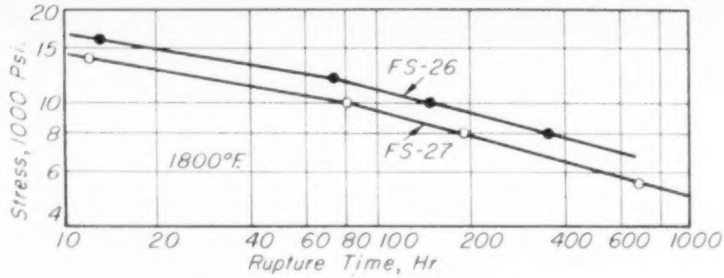


Fig. 2 – Stress-Rupture Curves for Two Grades of Cermets at 1800° F.

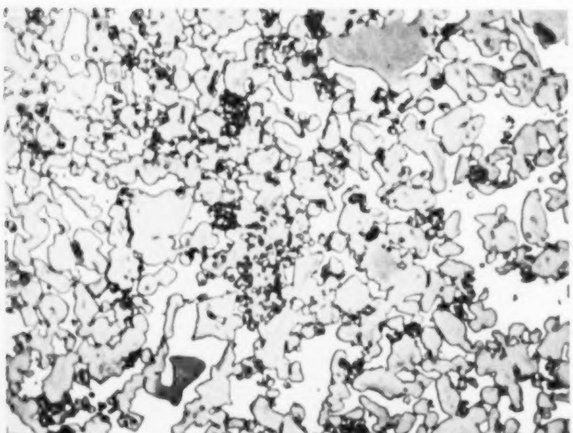
plus Cr) increases from 37 to 50%. Chromium imparts oxidation resistance to the cermets, and is relatively low on the list of strategic elements; it is less than 1% as strategic as columbium—another element used for this purpose.

The density varied between 6.00 and 6.55 g. per cc., depending on the amount and composition of the binder. The hardness ranged between Rockwell A-81 and 89. The modulus of rupture at room temperature varied from 150,000 to 180,000 psi. In general, as the amount of binder increased, the values for density increased, the hardness decreased, and the modulus of rupture strength increased.

Figure 1 illustrates a typical microstructure (Grade FS-27). Three phases are shown—titanium-carbide-rich solid solution, chromium-carbide-rich solid solution, and binder. The binder—a solid solution of nickel with a small amount of the two carbides—is represented by the white portions. Both carbides are gray and are differentiated by preferential etching. Electrolytic potassium hydroxide etches only the chromium carbide particles, leaving the titanium carbide and the binder particles unattacked.

A duplex structure of the titanium carbide

Fig. 1 – Typical Microstructure of Grade FS-27 Cermet. White areas are nickel solid solution, gray areas titanium carbide solid solution, and small dark areas chromium carbide solid solution. Etched electrolytically in 8% oxalic acid; 1500×



particles can be obtained by etching in Murakami's reagent. The outside or dark areas are titanium carbide which go into solution and reprecipitate from the binder during the sintering operation. The center or light areas are undissolved titanium carbide particles which do not go into solution in sintering. The average size of the titanium carbide particles is approximately 2½ μ.

The type of chromium carbide could not be identified by X-ray diffraction even though the specimen was powdered and the nickel binder removed by leaching. The amount of chromium carbide observed under the microscope was less than 5%.

The effect of temperature on tensile strength of FS-26 and FS-27 cermets is shown by the following data:

Temperature	Tensile Strength, Psi. FS-26	FS-27
80° F.	33,000	75,000
800	41,000	76,500
1200	48,000	75,000
1500	51,000	60,000
1800	41,000	35,000

The specimens were 2½ in. long by ½ in. wide by 0.2 in. thick, with a reduced section of approximately 1.3 x 0.2 x 0.2 in.; the ends of the specimens were V-shaped. The strength for FS-27 was fairly constant at about 75,000 psi. from room temperature to 1200° F., then dropped to 35,000 psi. at 1800° F. The reason for the increase in strength of FS-26 from 33,000 psi. at room temperature to 51,000 psi. at 1500° F. is not understood. It then dropped to 41,000 psi. at 1800° F. The elongation for both materials at 1800° F. was 1 to 2%. The specimens tested at lower temperatures showed no measurable ductility.

Figure 2 shows the rupture strengths for these same two grades at 1800° F. The same sized specimen was used for the stress-rupture tests as for the hot-tensile tests. The 100-hr. values of 9400 psi. for FS-27 and 11,100 psi. for FS-26

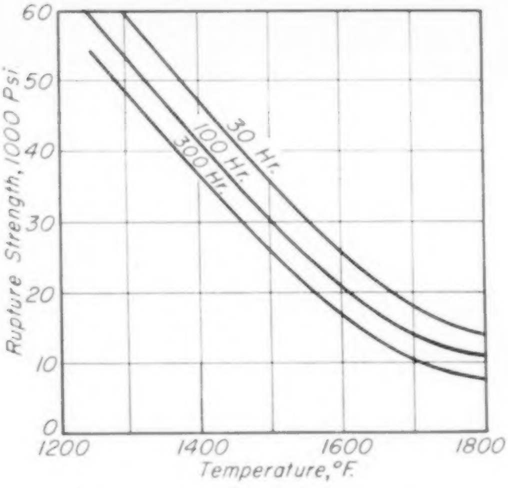


Fig. 3 – Effect of Temperature on Rupture Strength of Grade FS-26 Cermet

do not represent the ultimate in rupture strengths. For example, our experience has shown that addition of molybdenum materially increases the strength of cermets at 1800° F. However, an increase in rupture strength is accompanied by a loss of ductility and impact resistance. The 100-hr. rupture strength for X-40 – one of the best currently used alloys – is 11,300 psi. at this temperature. While the rupture strength for FS-26 compares favorably with X-40 at 1800° F., the cermet has a 26% lower density. This factor should be considered when comparing the cermets with metals, not only from the standpoint of weight saving in stationary parts, but also because low density is desirable in rotating parts to minimize centrifugal stresses. For instance, when a material having a 25% lower density is substituted for a second material, the stresses on the first material are reduced by as much as 25%.

In general, the ductility as measured in the stress-rupture test for these two cermets was fairly good; it ran from 3 to 8%. Better ductility was obtained with higher binder content of the cermet and with longer rupture times. Young's modulus at room temperature (75° F.) was 50.6 × 10^6 psi., and at 1300° F., it was 38.4 × 10^6 psi.

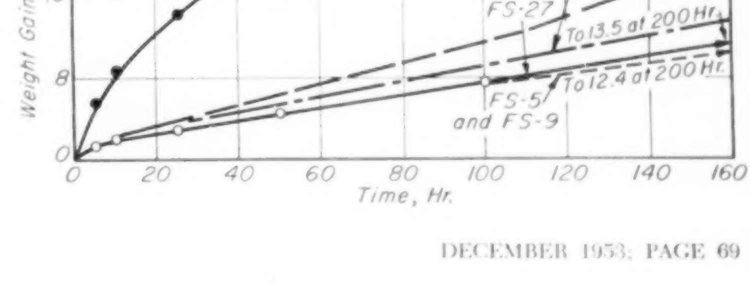
Figure 3 shows the effect of temperature on rupture strength of FS-26 for 30, 100, and 300 hr. The 100-hr. rupture decreased from 59,000 psi. at 1250° F. to 11,100 psi. at 1800° F. At the lower temperatures, FS-26 is slightly stronger than alloy X-40, while at 1800° F. the two materials have about the same strength. Elongation increased from 1% for 300-hr. rupture at 1300° F. to approximately 8% at 1800° F.

FORMATION OF SCALE

Figure 4 shows the gain in weight when these cermets were exposed to moist air at 1800° F. for time periods up to 200 hr. Air flowed into the furnace at a rate of 2 liters per min. Specimens ⅜ x ⅜ x ¼ in. were placed in small alundum boats, which were removed from the furnace at the end of 5, 10, 25, 50, 100, and 200 hr. In most of the tests the scale was strongly adherent, but when any scale flaked away, it was collected and weighed with the test piece. The curve for weight gain versus time shows a shape typical of the formation of a protective layer. FS-26 cermet gained 47.6 mg. per sq. cm. after 200 hr., while FS-27 gained only 13.5 mg. per sq. cm. FS-5 and FS-9 cermets, having the largest chromium contents, gained the smallest amount – approximately 12.4 mg. per sq. cm.

Metallographic examination indicated that oxidation began in binder areas adjacent to the carbide particles. It is believed that the binder areas were originally rich in chromium. During the time the specimens were sintered and later held at 1800° F., the chromium diffused into the carbide particles leaving the

Fig. 4 – Oxidation Curves for Various Cermets Showing Gain in Weight After Exposure to Moist Air at 1800° F.



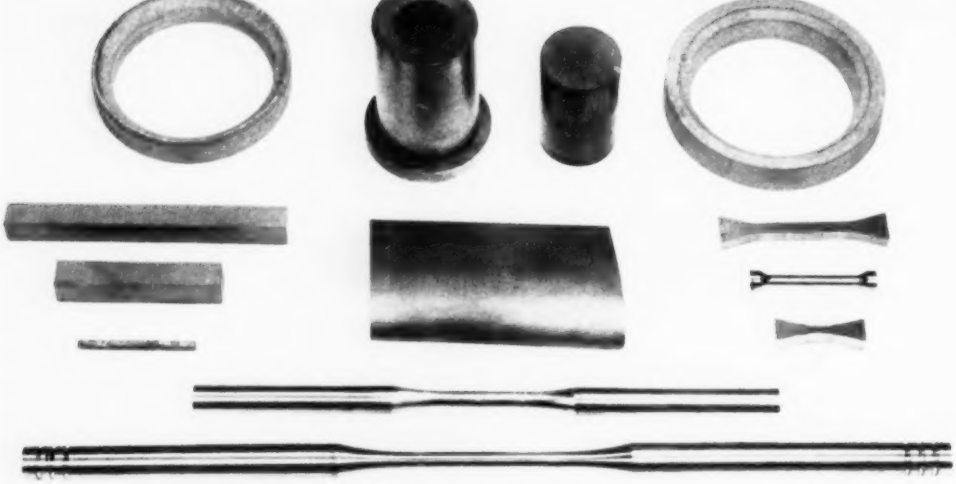


Fig. 5 – Various Parts and Specimens Made of Titanium Carbide Cermets, Including Intake and Exhaust Valve Rings, Nozzle Vane, a Pump Bearing, Impact Bar, and Tensile and Stress-Rupture Bars

adjacent binder areas deficient in chromium. After the binder areas adjacent to the carbide particles had oxidized, the titanium carbide areas were affected next. Finally, the binder areas rich in chromium oxidized.

Coefficient of thermal expansion was measured on 2-in. samples with the results shown in the following tabulation:

Temperature Range	FS-26	FS-27
68-212° F.	5.6*	5.8*
68-392	5.9	6.0
68-572	6.0	6.1
68-752	6.0	6.0
68-932	6.0	6.1
68-1292	6.0	6.2
68-1472	6.0	6.2

*$\times 10^{-6}$ per ° F.

These figures are low when compared to most iron and nickel-base alloys, and offer the advantage that vanes and blades can be designed with minimum clearance so they will not clash at high temperature.

The resistance to thermal shock of these cermets is good. This is surprising in materials with such low ductility, and must be attributed to the low thermal expansion and high thermal conductivity values, together with the fact that no structural transformations occur in these cermets on heating until the melting point is reached.

Unfortunately, cermets possess one serious drawback – namely, low impact resistance. Unnotched Charpy bars, 2.165 in. long by 0.394 in. square, of various cermet grades and of X-40 alloy were broken at various temperatures. The results shown in Table II reveal these cermets to be very brittle when compared to X-40, which is one of the most brittle of the commercial high-temperature alloys.

In conclusion, it is important to note that cermets with a range of properties can be produced by changes in composition. A variation in the amount of binder metal results in a change in toughness and resistance to thermal shock. The addition of alloying elements to the binder or to the carbide changes both strength and oxidation resistance. Probably no one composition will be ideal for all applications, but by adjusting properties in this way, the best compromise for a particular situation can be attained.

Table II – Toughness of Unnotched Charpy Bars

Grade	Impact Resistance, Ft-Lb.				
	80° F.	800° F.	1200° F.	1500° F.	1800° F.
FS-26*	4.5	4.5	4.9	4.8	4.4
FS-27*	4.7	4.9	4.8	5.9	5.8
X-40†	44.0	40.0	66.0	48.0	58.0

*Bars tested in a 16-ft-lb. Baldwin machine. The hammer has a 2-ft. drop with a striking velocity of 11 ft. per sec.

†Bars tested in a 264-ft-lb. Olsen machine. The hammer has a 4.4-ft. drop with a striking velocity of 16.5 ft. per sec.

By C. G. DUNN, Research Physicist
and G. C. NONKEN, Supervising Engineer
General Electric Co.
Pittsfield, Mass.

The G.E. Monogram Appears Essentially as a Single Crystal Against a Sparkling Background of Small Crystals in This Sample of Silicon Steel

Production of Oriented Single-Crystal Silicon Iron Sheet

Within the last decade, so-called grain-oriented silicon iron strip has become an important industrial product, by virtue of its magnetic properties, which approach those of a properly oriented single crystal. The marked improvement in magnetic properties of grain-oriented strip occurs when the path of the magnetic circuit coincides with the concentration of cube edge directions, since these directions in the crystal lattice are magnetically superior to other directions.

Properly oriented single crystals are, of course, ideal in this respect, and silicon iron in the form of single-crystal sheets represents what may be called the end point in the development of sharp single orientation textures.* Single-crystal sheets, however, cannot replace the cold rolled silicon iron with a sharp single orientation texture because single-crystal sheets are more difficult to produce, but they may find applications beyond those associated with the study of single-crystal materials.

A silicon iron sheet consisting of an "oriented" single crystal can be produced from a suitable polycrystalline sheet by recrystallizing it through the growth of a single nucleus. This "seed crystal" is previously grown in one end of the sheet and is mechanically positioned in the desired orientation by bending a portion of the sheet. (Dunn outlined part of this technique in

*The term "sharp single orientation texture", as used here, means that there is one and only one preferred crystal orientation and it is sharp or strong in contrast to a weak orientation, which begins to approach a condition of random orientations. If one expressed each degree of preferred orientation by a number, it would be the value of a standard deviation. For example, a single crystal would have a standard deviation of zero; a very strong preferred orientation, a standard deviation of, say, 5°; a moderately strong preferred orientation, a value of 15°. This field, however, has not yet reached the quantitative stage.

Growing a Seed Crystal

Transactions, A.I.M.E., Vol. 185, 1949, p. 72.) The success of the method depends on several important factors:

1. The crystal-growing characteristics of the polycrystalline sheet material used.
2. The amount of strain introduced into the metal adjacent to the seed crystal, occupying a narrow portion called the neck, which is plastically bent in the reorienting process.
3. The temperature gradient employed to maintain continuous growth of the seed crystal in the range 1500 to 2000° F.

POLYCRYSTALLINE SHEET MATERIAL

As stated above, not all polycrystalline sheet materials have the required crystal-growing characteristics. Also, the method of fabrication should be taken into consideration since there is a relationship between preferred orientations required for crystal growth and the amount and kind of hot or cold rolling and intermediate anneals. Regardless of these differences, the materials to be described in this article have in common a relatively fine-grained structure, which will be designated as the matrix.

Fig. 1–Sheet of Specially Prepared Silicon Iron With Several Recrystallization Grains in One End. Dotted line shows outline of area to be removed if Grain B is to be used as a seed crystal

A seed crystal must grow at the expense of the matrix under a driving force entirely derived from the grain-boundary energy of the fine-grained structure – or from a combination of grain-boundary energy and strain energy in the event that the matrix has been critically strained. If the driving force is to be constant, the matrix must be stable during growth of the seed crystal. This means that a portion of the matrix a small distance from the growing seed crystal must remain essentially unchanged during a high-temperature waiting period while the crystal traverses this distance. During the waiting period new grains must not appear in the matrix, and normal grain growth must not occur to any appreciable degree.

It is well known that the tendency toward normal grain growth increases with approach to 100% purity or, conversely, that impurities can be used to retard normal grain growth. Presence of a sharp single orientation texture in the matrix will also stabilize the structure. Present materials, however, have no sharp single orientation texture, and whatever preferred orientations are present can only tend to stabilize the structure. It is almost certain, therefore, that some impurities are essential in our method of growing single crystals of silicon iron. Likewise any operation that helps prepare a uniform grain structure in the polycrystalline sheet material can be employed to advantage, since such a structure is more stable than a heterogeneous one.

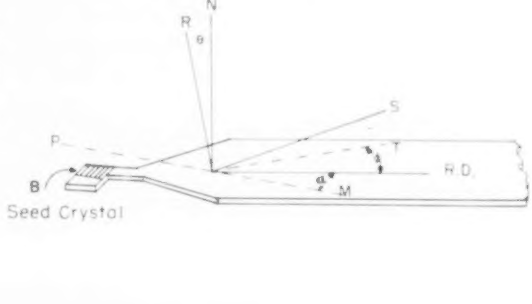
Three methods can be used to produce suitable sheet or strip material from commercial silicon iron with the following composition: 3.25% Si, 0.025 C, 0.034 Mn, 0.010 P, 0.017 S, 0.067 Ni, 0.068 Cu, 0.012 Sn, trace of Al and Cr. All three methods begin with a plate or band 0.10 in. thick that has been hot rolled from silicon iron ingots.

In Method I, pieces of the plate are reheated to about 1775° F. and hot rolled to 0.020 to 0.050 in. thick in packs. Sheets are annealed 15 to 20 hr. in hydrogen at about 1600° F. to remove residual stresses and lower the carbon content. After a critical tensile strain of about 2.5% elongation, the material is ready for use.

In Method II, the 0.10-in. hot rolled band is cold rolled to a final thickness between 0.020 and 0.050 in. in two steps. First, it is cold rolled to within 14% of the final gage and annealed for 20 min. (or less, depending on thickness) in air at about 1560° F. Scale is removed and it is then cold rolled the final 14%, annealed 1 hr. in hydrogen at 1475° F., and critically strained as in Method I.

In Method III, the band may be cold rolled to almost any desired final thickness in one or more stages. A penultimate open anneal in air at 1560° F. for a time long enough to reduce the carbon to about 0.005% is usually satisfac-

Fig. 2–Diagram Showing Directions R and S of Seed Crystal Relative to the Two Stationary Directions N and R.D. of the Sheet of Silicon Iron



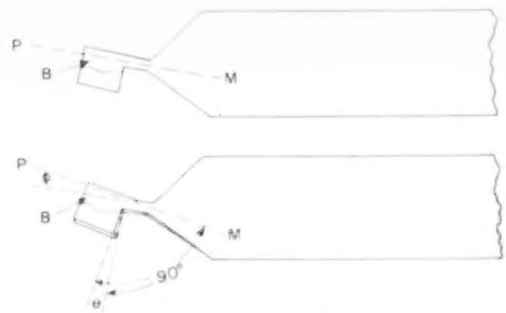


Fig. 3–Shape of Specimen and Isolated Seed Crystal Before Reorientation (Above) and After Reorientation (Below)

tory. Otherwise a decarburizing open anneal is recommended after the final cold reduction. The final reduction should preferably be in the range of 40 to 60%. Unlike Methods I and II, no critical strain is required; the matrix grain size produced by primary recrystallization is smaller and there is sufficient energy in the grain boundaries of the matrix to provide continuous growth of a single seed crystal. Although this method is the simplest of the three, it depends more critically on impurities and processing variations than the other two.

Method I is recommended if a wide variety of orientation is to be prepared or if a (100) or cube plane in particular is to be parallel with the sheet surface. On the other hand, if orientations are desired with the (110) or dodecahedral plane lying nearly parallel with the surface, then Methods II and III are recommended. A wider range of orientations can be obtained from Method II than from Method III, but if the cube-on-edge or (110) [001] orientation is desired, Method III generally is superior.

THE REORIENTING OF A SEED CRYSTAL

When silicon iron sheet prepared as described above is inserted a short distance into a high-temperature-gradient furnace, one or more recrystallization nuclei may be obtained, as shown schematically by A, B, C and D in Fig. 1. One nucleus – say grain B – may be selected as a seed crystal and its orientation determined. (For this purpose we prefer the transmission Laue method and the standard Laue patterns of Dunn and Martin described in *Transactions*, A.I.M.E., Vol. 185, 1949, p. 417.)

After the orientation of the seed crystal has been found (preferably in the form of a stereographic plot of cube poles), two directions (R and S in Fig. 2) are located which in reorientation are to be brought parallel respectively to the normal and to the long dimension of the sheet. This is done with the aid of a Wulff net; also, the required axes and angles of rotation for the reorientation can be determined easily using the Wulff net. If the final orientation is to have a cube plane in the plane of the sheet and a cube edge direction parallel with the long dimension of the sheet – a (100) [001] orientation – then both R and S will be cube edge directions. Another specific example, a (110) [001] orientation, would require R to be a face diagonal direction and S a cube edge direction. In general, however, R and S are two unspecified directions, 90° apart.

Putting a direction N normal to the sheet and a direction R.D. parallel with the long dimension, one obtains from the orientation analysis the relationships shown in Fig. 2. The directions R and N determine an angle of rotation Θ and an axis of rotation PM, which is 90° to both R and N. PM makes an angle α with R.D. When R has been rotated to N, S falls at T, which is at an angle Φ with R. D. Therefore a rotation of Θ degrees about PM followed by a rotation of Φ degrees about N makes R coincide with N and S coincide with R.D., giving the required final orientation. If the Φ rotation is taken first so that T coincides with R.D., the axis PM for the final rotation is found displaced Φ° either toward or away from R.D., depending on the direction of rotation.

Knowing the position of the axis PM and the amount of rotation required about N, one can plan how to isolate the seed crystal to minimize crystal growth 90° to R.D. The seed crystal is isolated by cutting away portions of the sheet as illustrated by the position of the dotted lines in Fig. 1. Generally, the axis PM either should be nearly parallel with the narrow portion (a neck portion adjacent to the seed crystal) or should be nearly perpendicular to the narrow or neck portion.

Figure 3 illustrates the former situation, and shows the shape of the sheet specimen after it has been cut along the dotted lines of Fig. 1. At this point all edges need to be heavily etched to remove excessively worked metal; otherwise unwanted nucleation may take place during crystal growth.

The apparatus used to reorient a seed crystal is shown in Fig. 4. A clamp holds and rotates the seed crystal and a table holds the end of the sheet adjacent to the neck portion. When the lower scale, which measures angles of rotation about N, is set correctly at the angle α so

Improved Reorienting Apparatus

that the horizontal axis coincides with the direction PM, the sheet specimen is placed on the table with its sides parallel to the reference lines and with the seed crystal resting freely in the jaws of the clamp, which at this point is at a zero setting of the upper scale. The jaws of the clamp are closed on the seed crystal, and the neck portion is bent as described previously.

During the reorientation operation the neck portion should be at red heat to facilitate plastic flow and minimize work hardening. Too high a temperature, however, would precipitate recrystallization, destroying the correct matrix structure. A small flame is adequate to apply heat locally; we use an oxygen-acetylene torch (Style 90, No. 4 tip), fed with natural gas instead of acetylene. After the two rotations have been completed, the specimen is fed, seed crystal first, into a furnace with a high temperature gradient for the final annealing operation.

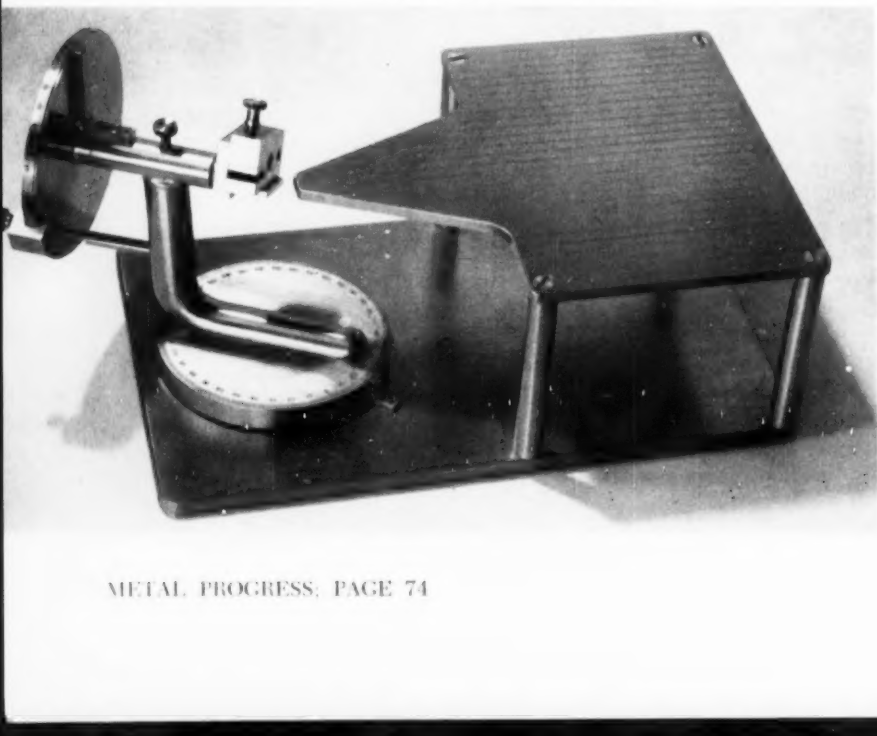
The crystal reorienting apparatus of Fig. 4 was developed for this investigation and appears to have certain advantages over other devices of this kind. Fujiwara and Tiedema in their work on aluminum have described devices that require two rotations to bring the direction R of Fig. 2 parallel with the normal N. Their apparatus is described in *Journal of Science*, Hiroshima University, Vol. 11, 1941, p. 89 and *Acta Crystallographica*, Vol. 2, 1949, p. 261. The sum of these two rotations can be proved to be larger than the equivalent single rotation about the axis PM. Hence, if only one direction R is to be fixed, rotation about a single axis, in the manner we recommend, minimizes the strain imposed in the neck portion. Fujiwara and Tiedema do not consider the second step; namely, the fixing of the direction S. If a third rotation is added to their two rotations, the straining of the neck portion is greater than that produced by using two rotations as described here. Our crystal reorienting apparatus can be made to do even more, because the two rotations may be carried out simultaneously instead of in succession, the result approaching that of a single rotation. A single rotation giving the required reorientation produces the lowest possible strain.

There are limitations in the shape of the neck and seed crystal portion of the specimen that the reorienting apparatus must also meet. The specimen must be able to pass through the small furnace apertures that are necessary to maintain a high temperature gradient. Except for this, the strain in the neck portion could be distributed over any size neck desired. In test experiments, successful results have been obtained after total rotations of more than 90°, which is more than ever is required. The main limitation to the amount of permissible rotation usually stems from the crystal-growing characteristics of the material. Twinning to a twin orientation during growth also is a problem.

As in other methods of producing single crystals, speed of growth is an important factor. In the temperature range for growth (above about 1550° F.) the temperature gradient decreases with increase in temperature, making it difficult to grow crystals at higher temperatures and therefore higher speeds. It is clear, therefore, that the higher the temperature gradients obtained the higher will be the permissible rate of growth.

Conversely, with a specified speed (that is, the rate at which the sheet is moved into the furnace), the higher the gradient at the growth temperature, the greater will be the chance for success. Much of our work has been done at speeds of about ¼ or ½ in. per hr., but considerably higher speeds have been found practical for certain purposes.

Fig. 4 Crystal Reorienting Apparatus



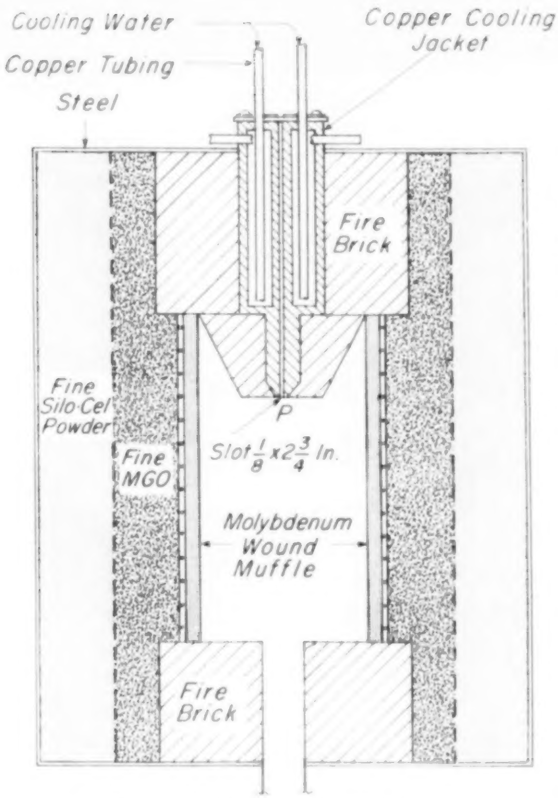


Fig. 5—Cross Section of High-Gradient Furnace (22½ In. High) for Growing Single Crystal

A furnace designed for growing a single large crystal in sheet form from a reoriented seed crystal must not only maintain a high temperature gradient in the range between 1500 and 2000° F., but must also meet certain other requirements such as good temperature control and stability, a hydrogen atmosphere, and a means of carrying the strip slowly and steadily into the furnace.

Fig. 6—Temperature Variation With Position as the Specimen Enters the Furnace

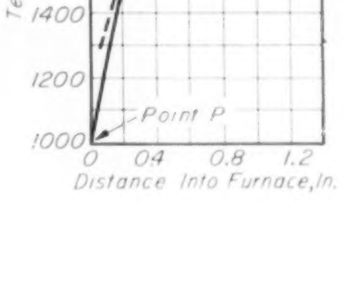


Figure 5 shows a cross section of a furnace which has been in use for a number of years. It consists of an alumina cylinder muffle wound with molybdenum wire and embedded in insulating refractory powder. A water-jacketed copper block which extends into the furnace to the point P forms the entrance slot for the silicon iron strip. Circulating water keeps the copper cool, and since the entrance slot extends well into the hot part of the furnace, the temperature increases very rapidly beyond point P.

Temperature variation with position in the furnace and its rate of increase measured from point P are shown in Fig. 6 for a given power input. If continuous growth occurred at a temperature of 1750° F., for example, the temperature gradient at the point of growth would be 1800° F. per in. With higher entry speed of the sheet, the temperature for growth would be higher, but the gradient would be lower.

SUMMARY

The steps for producing a large oriented single crystal of recrystallized silicon iron prepared by one of the three methods described may be summarized as follows:

1. One or more crystals are obtained in the end of a sheet (or strip) by placing it into the hot portion of a furnace with a high temperature gradient.
2. The sheet is removed and one crystal is selected for the seed crystal. It must be adjacent to the matrix.
3. A transmission Laue pattern of the seed crystal is obtained.
4. The orientation of the seed crystal is obtained from the Lauegram and the axes and angles of rotation to bring the crystal into the desired orientation are determined with the aid of a Wulff net.
5. The unwanted crystals are cut away as shown in Fig. 3, leaving the seed crystal connected to the strip by a narrow neck.
6. The seed crystal is clamped in the crystal reorienting apparatus (Fig. 4) and is changed to the desired orientation with respect to the sheet, by bending the neck of the specimen while at red heat.
7. The seed crystal in the new orientation is then made to grow and replace the matrix of the entire sheet by passing the sheet slowly through the hot zone of a high-temperature-gradient furnace.

By ALLEN T. BALDWIN
Hanson-Van Winkle-Munning Co.
Matawan, N.J.

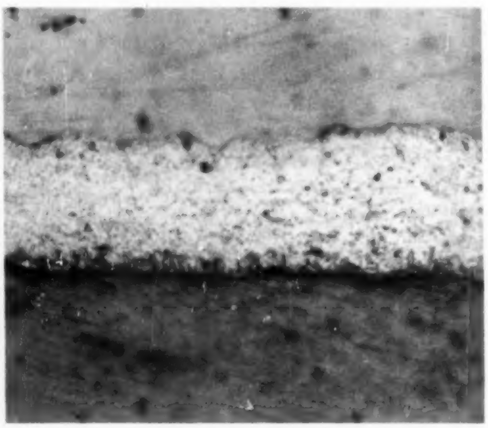
Electroplating Prior to Hot Galvanizing for Improved Results

As early as 1844 an American patent was granted on a process for the electroplating of tin on an iron object prior to its being dipped in molten zinc or other hot metal. Several patents have been granted during the last 100 years dealing with the idea of using various metals for electroplating the iron object to be ultimately hot galvanized. In the opinion of the inventors, such a preliminary electroplate would assure a more satisfactory final coating.

More recently, the practice in hot galvanizing has been to introduce another metal in quantities much less than 1% into the molten zinc and depend on its presence for such beneficial effects as are sought. The use of aluminum in this fashion has become a broad practice because it has resulted in the production of hot galvanized coatings of distinctive and desirable characteristics. Consequently, experiments were undertaken with a view of determining whether introducing some of these metals in "trace" amounts as an electroplated film might lead to the development of other methods of finishing those products which generally are hot dip galvanized by a continuous operation.

These studies were based on certain familiar assumptions concerning the conditions which influence the adherence and ductility of the hot dip zinc coating. Basic among these are the assumptions that the solubility of the iron in the zinc and the diffusion of this dissolved

Fig. 1—Commercial Hot Galvanized Steel. Immersed for about 3 sec. at 850 to 860° F. in zinc containing 0.12 to 0.15% Al. All micros 1000×



iron throughout the coating are important. Attention is directed, therefore, to the temperature of the zinc bath, the immersion time, the solubility and diffusion of the iron in the zinc, and the effects of minor amounts of other metals on the nature of the coating. Since facilities were available for electroplating thin films of various metals on steel panels, the experiments began at this point. This article is a record of the outcome.

Panels of A.I.S.I. 1010 having a high finish and measuring 0.029 x 3 x 8 in. were used in these studies. The coatings listed below were put on both sides of the panels by standard commercial plating methods.

Metal Plated	Thickness, in In.	Weight, Oz. per Sq.Ft.
Zinc	0.000033	0.02145
Tin	0.000033	0.02003
Nickel	0.00002	0.01442
Iron	0.0002	0.1300

The plate thicknesses were chosen as ones quickly and readily obtained, and the intention is to continue the study by using other values which may be either thinner or thicker. In production, the thought is to follow any pickling or other cleaning step with a suitable plate so that the strip steel could be preheated if desired, and could possibly be prefluxed and enter the molten zinc through a flux blanket.

Panels plated in our laboratory have been hot dipped successfully several days later without further treatment by passing them through a fusion of No. 20 flux on the molten zinc at 845 to 850° F. The galvanizing unit used held 20 tons of zinc ("Prime Western") in which there may have been very minute traces of aluminum from additions that were made during its use prior to the tests.

Unplated panels of the same steel as used under the plates provided a basis of comparison for the two methods of galvanizing. The electroplated iron was included to note if such a surface increased the diffusion of iron through the final coat. Zinc plating was used to note the possibility of minimizing the content of diffused iron. Tin was tried because it is another metal commonly used in small amounts to increase the effectiveness of the galvanizing. Nickel was used since it is easily applied in thin films and would favorably permit preheating. This series would have included aluminum as a thin film, but because it is not readily electroplated, its performance will be observed after another method of application of a thin film can be carried out.

The samples not plated and those with an electroplated film of iron were first dipped in a No. 20 flux wash. The other electroplated samples were not given the preflux dip. To control the dipping time, each plate had a heavy weight wired to one corner and another wire attached to the corner diagonally opposite for use as a handle. When the weight had lost buoyancy, the plates were allowed to sink vertically through the fused flux layer and remain in the hot zinc for the predetermined times. These are given in the captions for the micrographs. The original plates weighed approximately 90 g. each, and after coating weighed

Fig. 2—Coated by Sendzimir Process in 4 Sec. at 850 to 860° F.

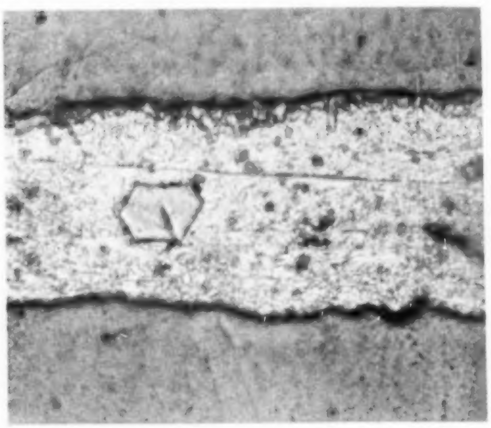
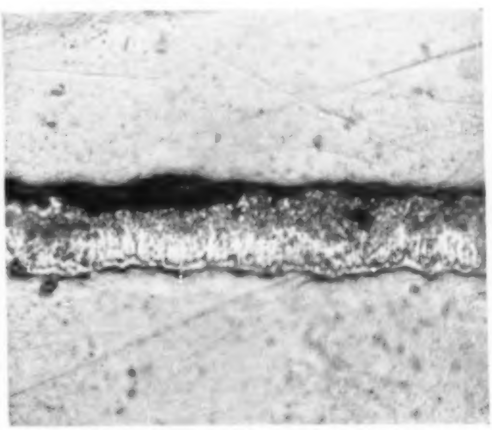


Fig. 3—Coated in Lead-Zinc Bath, Immersion in Zinc Layer (Containing no Aluminum) Less Than 1 Sec.



approximately 104 g. They were quenched in hot water immediately after removal from the molten zinc.

Because immersions ranging from 7 to 9 sec. were required to secure a completely smooth coverage, 10 sec. was adopted as a uniform minimum time. This was a disappointment because immersion times less than 5 sec. had been sought; it appears, therefore, that a continuous process would require some preheating of the strip in order to keep immersion time at a minimum. When the samples were withdrawn from the zinc bath, the hot metal ran off the surface of the panels plated with tin and nickel more freely than from the others.

It was felt that micrographic examination of sections of each group would be more useful than an evaluation through adherence or bending tests on such small plates with their heavy weight of coating. These micrographs are Fig. 4 to 8. All metallographic samples were mounted similarly and, with the plated ones, the three tests of each lot were included in a single mounting separated by steel spacers. Magnesium oxide ("Shamva") was used in polishing. Etching was done with a fresh mixture of 25 ml. of amyl alcohol and 1 drop of concentrated nitric acid for 10 to 20 sec. An oil immersion objective of NA 1.3 was used and exposures were made on "ortho commercial" plates (sensitive to blue) through a blue filter.

Figures 1 and 2 are typical of currently produced commercial quality galvanizing on steel by methods using aluminum as a means of coating control. Figure 2 shows the Sendzimir-process coating; Fig. 3 is of a coating obtained on a narrow strip passing through a lead bath for about 10 ft. and emerging through a thin layer of molten zinc. Here, total time in the hot metal is about 8 sec., of which less than 1 sec. is spent in the zinc layer. The coating in Fig. 3 is about 0.0006 in. thick and weighs 0.36 oz. per sq.ft. The close similarity of the structure to that shown in Fig. 4 for unplated panels suggests the thought that the passage of this strip through the lead section of the bath initiated the attack on the base iron. Otherwise, it is reasonable to assume that a regular series of zinc phases is created in less than 1 sec. at about 850° F.

The structure for plain steel in Fig. 4 appears to be that usually reported for hot dip zinc coatings where there is little or no aluminum present. At the time these exposures were made, it was apparent that what appears here as the first zone (gamma) above the steel base was in reality a divided one with a finer line also running in a horizontal direction. However, because no structural difference could be detected in the surfaces below the higher one of these lines, it was decided to present the micrographs which illustrate the areas of greater diffusion more clearly.

The effect of the electroplated iron film is shown in Fig. 5. Study of the sections and the prints gives the impression that the diffusion has been more uniform, and possibly the layers up to the eta phase are thicker than on unplated

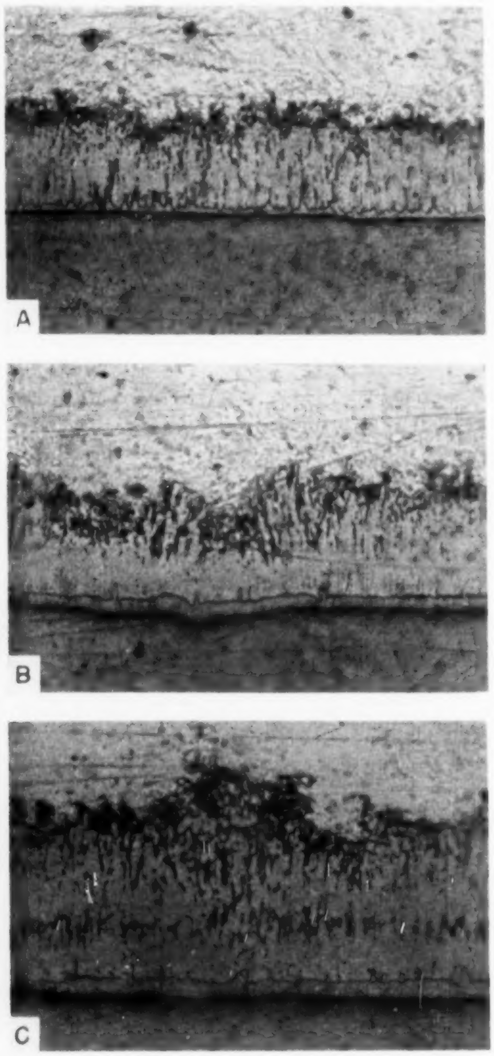


Fig. 4 – Samples Without Preplate, Galvanized at 850° F. for (A) 10 Sec., (B) 30 Sec., (C) 60 Sec.

Micros Compare Various Metals

steel. At 60 sec. immersion there appears to be a tendency for the gamma layer to lose its smooth, uniform appearance.

The general preference in industry to have tin available for additions to the molten zinc led to including this metal in the series, and the usual highly fluid condition of metal draining from the test panels was met. Figure 6 shows sections of two tests; attention is drawn to the diffusion pattern at the upper edge of the gamma layer for the sample receiving 60-sec. immersion (Fig. 6B).

The panels electroplated with zinc are shown in Fig. 7. These coatings seem to have horizontal lines of phase separation which are more even and uniform. The vertical structure appears denser and less displaced from the vertical.

Probably the most interesting test was on the nickel plated panels, the results of which are shown in Fig. 8. There is a very thin film next to the steel base which does not show clearly here. In Fig. 8A (10-sec. dip) discrete particles seem to be suspended in a second mass. After

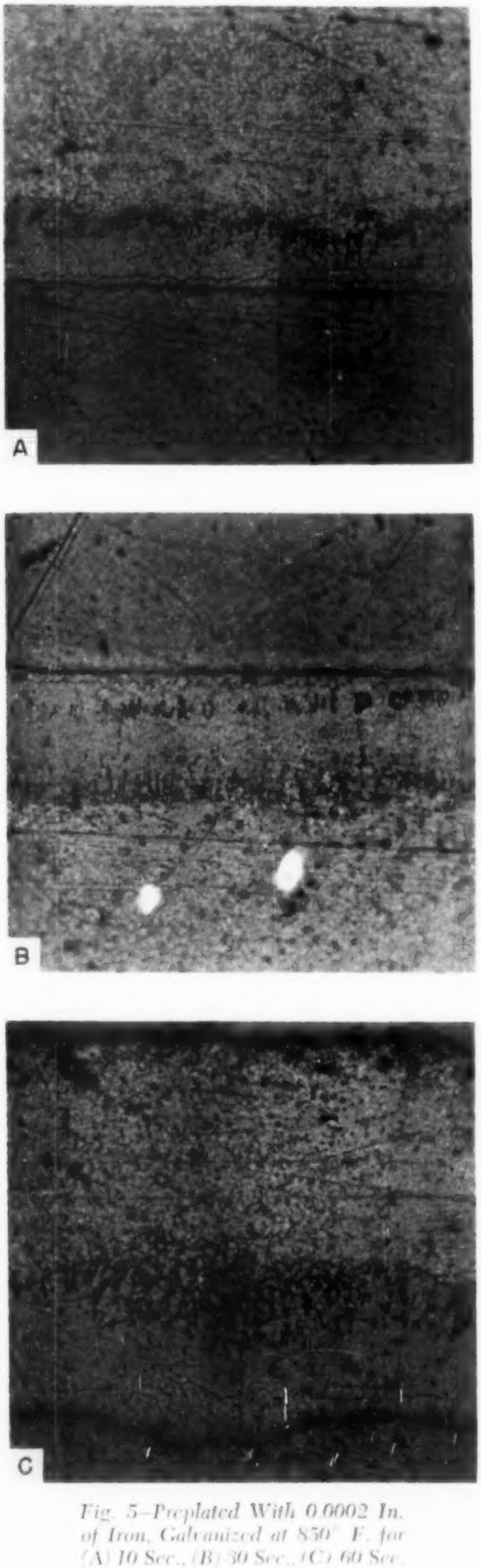
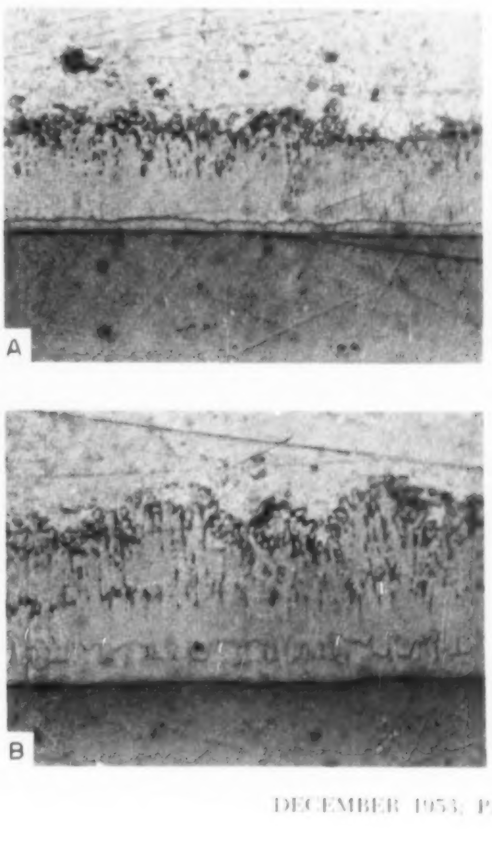


Fig. 5—Preplated With 0.0002 In. of Iron, Galvanized at 850° F. for (A) 10 Sec., (B) 30 Sec., (C) 60 Sec.

Fig. 6—Preplated With 0.000033 In. of Tin, Galvanized at 850° F. for (A) 16.8 Sec., (B) 60 Sec.



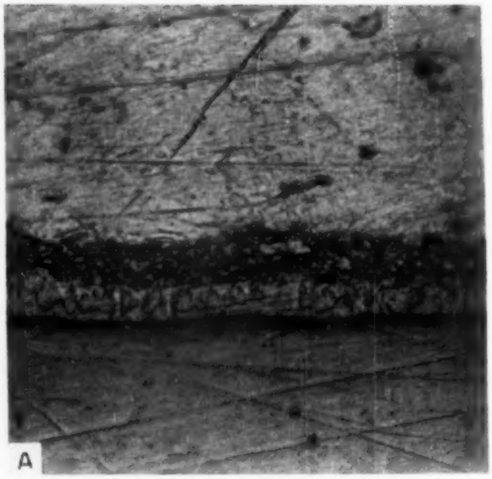
Heat Requirements for Galvanizing

30 sec. of immersion (Fig. 8B), this area has become more uniform, and in 60 sec. (Fig. 8C) these particles have taken on a distinct dog-tooth shape and have moved away from the steel base. Reference to the nickel-zinc phase diagrams by J. Schram (*Zeitschrift für Metallkunde*, Vol. 30, April 1938, p. 132) discloses a eutectic at 418.5° C. with 0.04% Ni in the eta phase of Zn and 0.25% Ni in the liquidus.

At this time we do not feel justified in drawing many definite conclusions from these experiments or from the micrographs. Some impressions have arisen, however, which we feel will justify the continuation of studies in this direction. Some of these are:

1. Electroplated films may be used to improve the process of hot galvanizing strip steel by protecting the treated surfaces of the steel prior to coating. Any steel surface must be completely free of oxide and nonmetallic materials before galvanizing. If it is not, molten zinc will not alloy with the ferrous surface. Surfaces can be freed of iron oxide by ordinary pickling, but under ordinary conditions, particularly where continuous methods are in use, iron surfaces tend strongly to re-oxidize. A film of nonferrous metal plated to the ferrous surface can retard, and possibly prevent, the formation of any iron oxide on the surface. The film itself might oxidize, but these oxides would not be as harmful.

2. No radically new phase pattern appears in the coatings, except possibly with nickel.

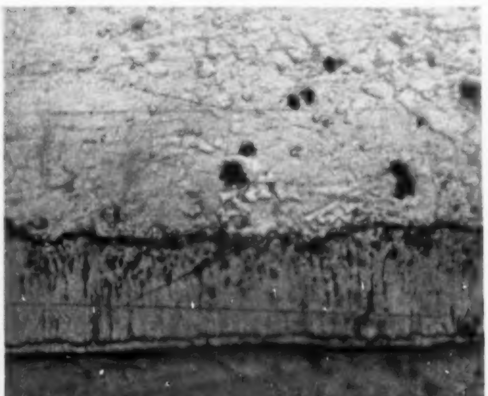


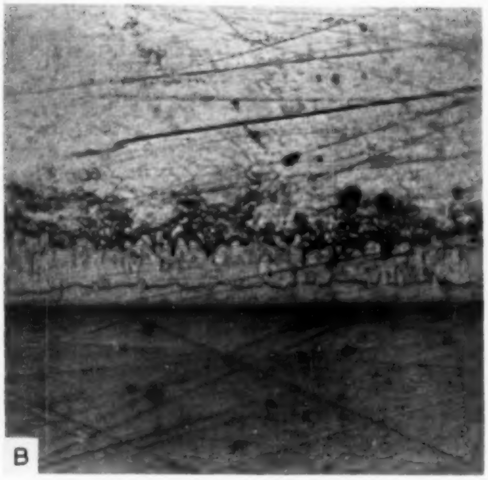
3. Thin electroplated surfaces can be used as a means of establishing a desired surface for hot galvanizing.

4. A method of measuring the effect of time and temperature on the diffusion of iron or other metal through the zinc coating might be developed. Apparently, as the phases form, the boundaries between them are irregular, then with time become more regular and with still longer time lose this regularity. By "regularity" is meant the smoothness or evenness of the lines separating the phases.

The place where coating quality is finally established is in the zinc bath itself, and a feature of the existing processes for steel strip is the success they have in presenting uniform surfaces to molten zinc for coating in short immersion times. These experiments indicate that it is de-

Fig. 7—Preplated With 0.000033 In. of Zinc, Galzanized at 850° F. for (A) 10 Sec., (B) 30 Sec., (C) 60 Sec.





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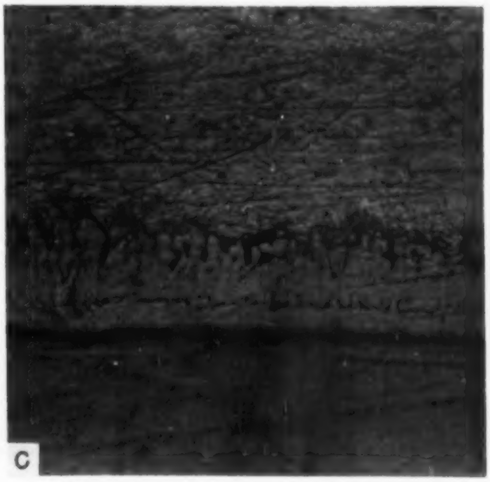

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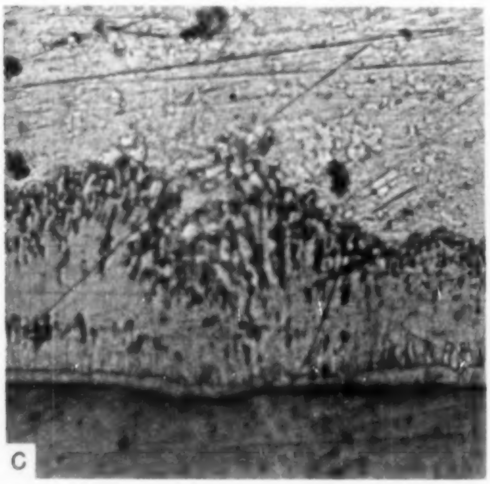
Fig. 8—Preplated With 0.00002 In. of Nickel, Galvanized at 850° F. for (A) 10 Sec., (B) 30 Sec., (C) 60 Sec.

sirable to keep the immersion period shorter than the full time required to bring the steel itself up to zinc kettle temperature. This means preheating, which in turn calls for maintenance of the proper steel surface, as apparently is done by a preliminary electroplate of a thin film. Such electroplated surfaces can be preheated rather simply, but probably not to the temperature of the molten zinc.

In practice, the total requirement to heat a pound of steel and melt the zinc to coat it ranges from a possible low value of 180 Btu. to approximately 500 Btu. when the heat is supplied through the side walls of the pot. Highly efficient installations require 200 to 350 Btu. per lb. of work.

This use of about double the basic heat requirement wherever heat is supplied through the side walls invites consideration of heating methods where the heat source functions by direct radiation on a properly protected zinc surface. The use of electric resistors as described by N. Thoren ("Top-Heated Galvanizing Bath at Virsbo", Preprint No. 6, Düsseldorf Conference, 1952) illustrates one application of this type. Records derived from substantial quantities of production indicate total heat requirement of 150 Btu. per lb. where approximately 12,000 Btu. is released for each square foot of heating area. It would appear, therefore, that the initial accomplishments by this method of heating would justify consideration of it as a more efficient and better controlled heating at the actual point of use.



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In conclusion, it should be repeated that these experiments were undertaken to determine if very thin electroplated films would be useful in carrying out the hot galvanizing operation. Such a study would call for consideration of the various steps in the hot galvanizing process and has led to the comments on heat application. As for the other steps, the insertion of an electroplating stage does not present complicated or costly problems in methods. Likewise, the decision to preflux and to maintain a flux fusion on the molten zinc will be influenced by the selection of materials suitable for operation on nonferrous surfaces. This, of course, is a different problem than that met with ferrous surfaces and broadens the possibilities of selection. Finally, these experiments must be looked upon as merely the first step in a continuing development program.

A Method of Metallurgical Microspectroscopy

By FORD R. BRYAN and CLEO H. NEVEU
Scientific Laboratory
Ford Motor Co., Dearborn, Mich.

To assist metallurgists in identifying microconstituents of metallurgical specimens, spectroscopists for several years have been working on the problem of obtaining a sample restricted to a very small area of the specimen. G. Scheibe and J. Martin devised specialized equipment as early as 1939 (*Spectrochimica Acta*, Vol. 1, 1939) to obtain such a sample. Their procedure employed a microspark source which discharged through a fine quartz capillary onto the area to be analyzed. Surface areas of 0.05 mm. diameter were reported to be successfully identified. Later, others (*Journal* of the Optical Society of America, Vol. 31, 1941 and Vol. 37, 1947) employed modified versions of this method. In 1941 G. Thanaheiser and J. Heyes (*Archiv fur das Eisenhuttenwesen*, Vol. 14, 1941) reported using a small hole drilled through a thin mica sheet to confine a spark to a small area of metal. Barker, Convey, and Oldfield, in a series of publications (*Engineering*, Vol. 152, 1941, and Vol. 160, 1945, and *Iron and Steel*, Vol. 18, 1945) reported the use of pointed graphite and metal counter electrodes for the analysis of segregates in metals. Hurwitz has continued work on the quantitative determination of segregation in metals (*Journal* of the Optical Society of America, Vol. 42, 1952) by means of traversing metal surfaces with a microspark, thereby obtaining spectra from a path 0.6 mm. wide.

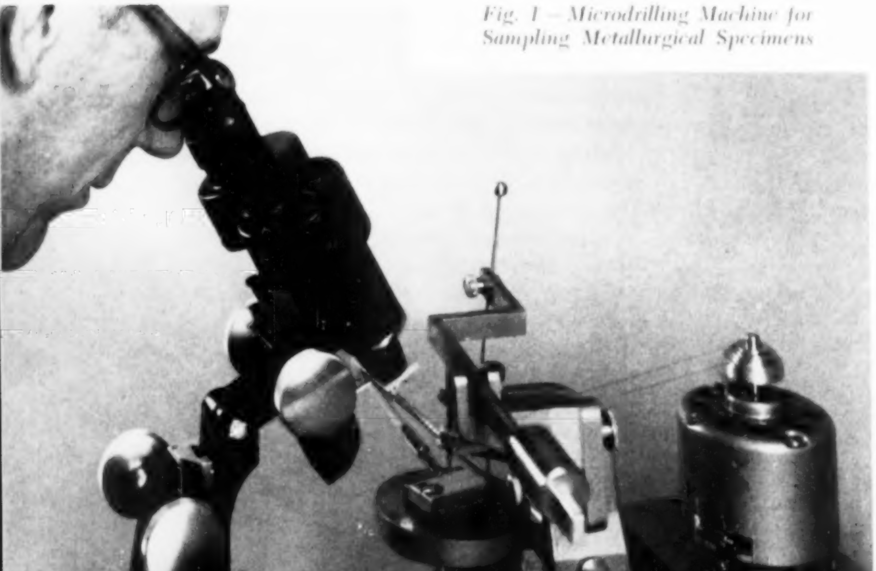


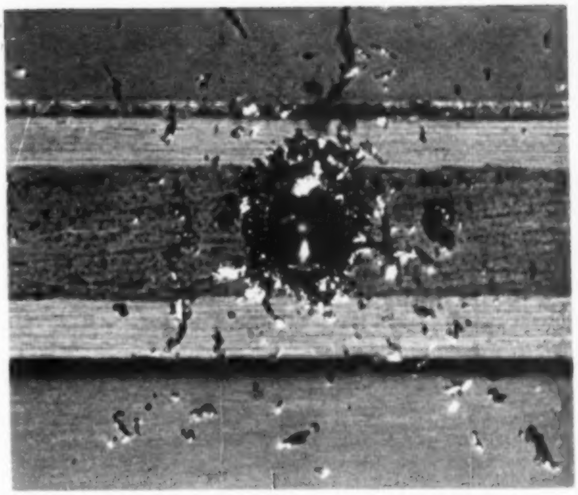
Fig. 1 – Microdrilling Machine for Sampling Metallurgical Specimens

One of the difficulties encountered by spectroscopists in using the methods reported by these investigators has been the necessity of constructing specialized equipment. The procedure to be described has the advantage of utilizing any standard spectrograph and source. The small amount of specialized equipment needed is available commercially.

PRINCIPLE OF THE METHOD

This new method of identifying metallic constituents consists of drilling out the minute portion to be analyzed, flowing collodion over the resulting chips, and transferring the collodion together with chips to

Fig. 2(A) – Mounted Cross Section of Silver Solder Sheet With Sample Chips Made With 0.003-In. Microdrill



a pure carbon electrode for analysis in a standard spectrographic arc.

The steps of the sampling procedure are illustrated in Fig. 2 in which (A) is a mounted section of silver solder sheet consisting of a center strip of 0.005-in. copper between two layers of 0.003-in. silver with chips drilled from the copper layer by means of 0.003-in. diameter microdrill, (B) is a portion of a collodion droplet covering chips, and (C) is the hole remaining after collodion and embedded chips are stripped from the specimens. The simple metallic spectrum of pure copper is obtained when the collodion and chips are arced in a graphite electrode.

Because 0.1 microgram of metal can usually produce a spectrum, drillings from a 0.001-in. diameter hole of equal depth can usually be identified as to major constituent. Drillings from 0.002 and 0.003-in. holes often provide more complete spectra and identification of high-alloy constituents.

DRILLING MACHINE

Several drilling machines reported to be capable of utilizing 0.001-in. drills are commercially available. The one used in this work was National Jet Co.'s Model 7A, (Fig. 1), and is capable of drilling holes as small as 0.00025 in. in diameter in relatively soft steels. The mechanism employs no chuck, but instead spindle and drill are a single concentric piece which revolves in a jeweled V-block. The motor is mounted separately from the drilling machine to provide essentially vibration-free spindle speeds from 2500 to 5000 rpm.

Pivot drills of tungsten steel, hardened to Rockwell C-65 to 68 are used in sizes ranging from 0.001 to 0.005 in. in diameter. The shank itself becomes the spindle of the machine.

The microscope used in viewing the sample and drilling operations is a Spencer stereoscopic shop microscope equipped with 18× paired eyepieces. Visual magnification is selected to match the leverage ratio of the drill controls, as well as to allow identification and centering of the sample area to be drilled.

Sample Preparation – The constituent to be identified is usually first observed in a mounted and polished specimen prepared for micro-

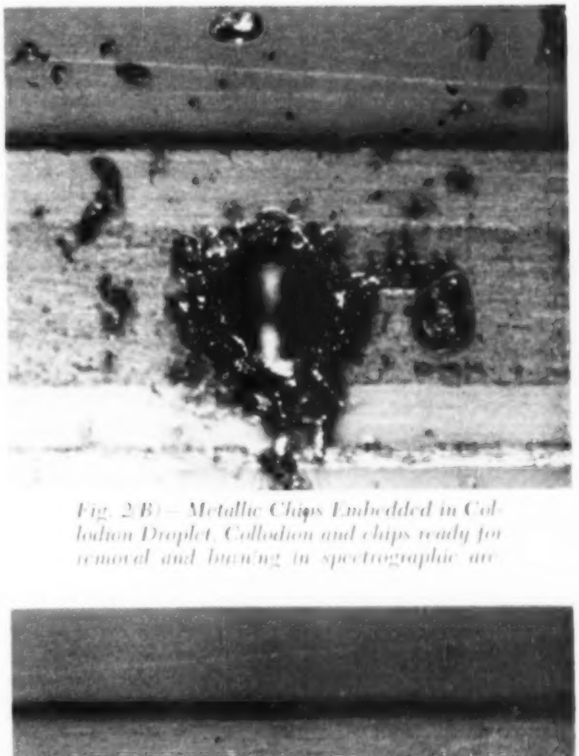


Fig. 2(B) – Metallic Chips Embedded in Collodion Droplet. Collodion and chips ready for removal and burning in spectrographic arc

Fig. 2(C) – Hole Remaining in Specimen After Stripping Collodion and Embedded Chips

Quantitative Analysis of Constituents

scopic examination. The typical metallographic mounting for the specimen also provides a very satisfactory means of manipulating the sample in the drilling machine. The small area to be analyzed spectrographically is first located by the metallurgist under the metallographic microscope before the specimen is transferred to the microdrilling machine.

The size of the area to be sampled and the appropriate drill size can be determined by viewing the specimen under a known magnification. In general, drill size is selected to be equal to, or less than, the surface area to be removed. The simplest qualitative analysis is derived from a single drilling restricted to the individual area in question. Qualitative information can also be obtained when drill size is relatively large as compared to the unknown constituent, provided a second drilling from the surrounding material is used for comparison.

Quantitative analysis requires sufficient drilled material to provide a more complete spectrum than required for qualitative identification. If the unknown constituent occurs in large formations, a single large drilling may provide a suitable spectrum for quantitative estimations. If the unknown constituent exists only in very minute areas, an appropriately located series of drillings of smaller diameter will provide the necessary mass of representative material necessary for quantitative results. At best, however, quantitative results by microspectroscopy are quite inaccurate as compared with conventional spectroscopy.

Drilling Techniques – Drilling must, of course, be confined to the proper area and depth, and a satisfactory quantity of chips should be obtained. Equally self-evident is that the drill be of appropriate diameter and, as an aid in controlling hole size, be reasonably straight to avoid excessive run-out. To control the exact location of the hole, the microscope should be focused on the surface of the specimen so that it and the drill tip are in focus at time of contact. The bottom of the specimen mount should be flat to prevent wobble, and to offer sufficient friction to prevent its rotating under the drill. Also, the surface of the specimen should be perpendicular to the axis of drill rotation to prevent sliding and bending of the drill as it contacts the sample. A long pulley-cord and rigid table are of some advantage in minimizing the transfer of motor vibration to the drill.

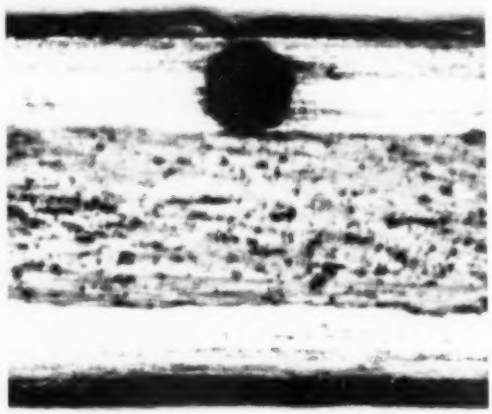
As a rule, any visible chip is sufficient to provide a qualitative spectrum of the major metallic element. Recovery of sufficient chips from very small holes requires that the spindle speed be low enough to prevent chips from scattering too far from the hole. On the other hand, chips sometimes cling to the drill and defy removal when the drill becomes magnetized.

There are several factors which can lead to frequent drill breakage. Under similar conditions, the smaller drills, of course, break more easily than the larger ones. Samples approaching the hardness of the drill are particularly hazardous and should be drilled by imparting a reciprocating action to the drill point. Spindle speed should be less than 3000 rpm. rather than higher, according to Cupler (*Tool Engineer*, April, 1950). Carbon tetrachloride is considered the best lubricant and coolant, and the quantity required should not be excessively toxic.

Recovery of Chips – After drilling is completed, a drop of 10% solution of flexible collodion in butyl acetate is flowed over the chips. Within a few minutes, the collodion, together with embedded chips, can be stripped from the surface of the specimen. Other organic strippable films may be used, providing the material does not contribute to the metallic spectra. Likewise, solvents other than butyl acetate may be employed to hasten or retard the rate of evaporation.

Electrode Preparation – The collodion-embedded sample is placed on the end of a spectroscopically pure graphite electrode and moistened with a drop of butyl acetate for improved adhesion of the collodion to the electrode. (Even the best graphite electrodes contain traces of metallic elements; therefore it is

Fig. 3 – Hole Resulting From Removal of Sample From 0.003-In. Layer by Means of 0.002-In. Microdrill. Silver, copper, zinc, and cadmium were identified in sample

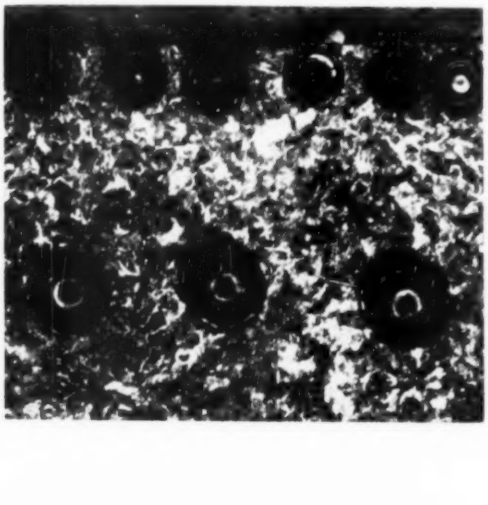


wise to use the highest purity obtainable.) It is advisable to arc a pair of bare control electrodes as a comparison spectrum with each sample spectrum in order to distinguish the sample material from electrode impurities. Graphite rods ⅛ in. diameter and ⅜ in. long with flat cut ends are appropriate. These should be purchased purified after machining, and should be handled with forceps so as to prevent any contamination.

Arcing–The electrode which holds the sample is placed in the bottom clamp at a gap distance of about 2 mm. from the upper counter electrode. There should be no pre-exposure, and the exposure should be short so that the electrode background is not excessive. The chips are consumed within a few seconds so that a total exposure of 10 sec. is adequate. The usual condensing lens and source-to-slit distance should be satisfactory. However, where alternate lens systems are readily available, the one possessing the greatest speed would be most desirable. A 2-amp. arc of either an alternating or direct current is appropriate. Current, voltage, and degree of regulation are apparently not critical for this purpose.

Spectra–Spectrum analysis No. 1 plates or film are usually employed, and the customary rapid processing procedure may be used. If an emulsion of greater sensitivity appears to be necessary, Eastman Type 103-0 should be tried. For wavelength comparison, a spectrum of iron adjacent to the sample spectrum is useful, since iron lines may be easily identified by means of available atlases. When the area drilled consists of an abnormality in an otherwise homogeneous specimen of known composition, it is often desirable to have a spectrum of this surrounding material on the same film for comparison.

Fig. 4 – Samplings Taken From Boron Steel to Determine Relative Concentration of Boron at the Surface (0.003-In. Drill) as Compared With Concentration in Center of Specimen (0.005-In. Drill)



Since the full slit aperture of the spectrograph can be uniformly illuminated, it is possible to make microphotometer measurements on the spectral lines. When the sample contains high percentages of more than one element, it is possible to make semiquantitative determinations from microphotometer readings on the sample spectrum and corresponding readings on the spectra of comparison standards. Also, if sufficient sample is arced, it is possible to determine relatively minor constituents quantitatively by the microphotometering of minor constituent lines in comparison with a major constituent line. This procedure corresponds to the common internal reference line method.

APPLICATIONS

This microdrilling technique can be applied to several classes of metallurgical problems. Metallic, and sometimes nonmetallic, inclusions can be identified in a matrix of normal material. A series of closely spaced samplings can provide evidence of segregation and identify segregates. Metallic constituents of individual crystals can be identified, providing the structure is not too fine. Underlying layers of multiple platings can be sampled and identified individually by drilling into their cross sections. By means of a series of drillings, one can sometimes determine diffusion characteristics of metals.

Figure 3 illustrates how a 0.003-in. plating was sampled by means of a 0.002-in. diameter drill to determine the purity of the plating. Copper, zinc, and cadmium were identified in addition to the major element, silver. Since the alloy was later found to contain only 15% Cu and 15% Zn, the procedure allowed the detection of approximately 0.1 microgram of each of these elements.

Another specific application is illustrated by Fig. 4. A specimen of 0.01% boron steel was sampled to compare the boron concentration along the edge with the concentration in the center of the section. Use of the microdrill made it possible to confine the sampling to within 0.005 in. of the edge. The method is sufficiently sensitive that the boron line from each set of drillings can be measured on a microphotometer and compared with an iron reference line for a quantitative determination.

Measurement of Case Depth

By DALE J. WRIGHT, General Superintendent
Heat Treat Div., Caterpillar Tractor Co.
Peoria, Ill.

Numerous methods are employed throughout industry to measure the depth of carburized cases on steel, largely because there is apparently no standardized procedure which is acceptable to all. Articles have been published describing various "approved" or "standard" procedures, but generally each company or industry has preferred to apply its own particular technique based on its own interpretation of case depth and the availability of either shop or laboratory equipment.

Until approximately seven years ago, the heat treating division of Caterpillar Tractor Co. encountered inconsistencies in case depths on test bars which were not always explainable. Each such instance involved considerable extra expense because of additional testing and destruction of piece parts. An analysis of the problem revealed that very often the fault was in the manner of determining case depth rather than in the carburizing operation. At that time, therefore, we set out to define the most applicable and economical manner of checking this metallurgical quality and standardizing accordingly. The objectives which would have to be met for our use were as follows:

1. Determinations must be accurate and repetitive. The method must eliminate differences of judgment between people making the determination, something we found to be the greatest problem in our previous practices.

2. Determinations must be made quickly so that "in process" heats can be checked at any time without delay.

3. The procedure must be simple so as not to demand highly skilled technicians, a requirement particularly important during week-end or holiday operation.

4. Equipment should be relatively inexpensive and durable, and cost of individual determinations be as low as possible. Importance of the latter consideration is attested by the fact that we average 250 determinations a day.

5. The method used should represent a measure of the control of the carburizing process, and not attempt to evaluate other variables such as material or design of the piece.

6. The determination should indicate a case depth which would find acceptance under a broad interpretation of the term "effective" depth of case.

A number of approaches were tried during the investigation for a method which would meet these requirements. Thus, test bars of carbon and alloy steels were etched or heat tinted to resolve the carburized case for its measurement with a special scale. Brinell or equivalent low-power magnifications in conjunction with appropriately calibrated lineal divisions were used to measure the case on fractured or polished and etched transverse sections. Two other ideas studied were hardness tests on step-ground and tapered bars and transverse sections; and the microscopic examination of carburized, and of carburized and hardened bars which had been tempered at 1100° F. in cast iron borings.

In keeping with our stated objectives, we decided on a combination of the first two methods, regulated so as to control the known variables and made to conform easily with all of our needs. After many years of its use we are well pleased with the results, and confident that any troubles we may encounter are not due to the method of checking case depth.

The following describes the procedure we employ, which is actually very simple to apply after a brief initial instruction.

Instrument Eliminates Human Element

Description of Test Bars – Test bars are procured from a mill heat of known characteristics and in sufficient quantity to last a number of years. The cold finished bars are 7/16 in. square and 3½ in. long, and a hole is drilled near one end on those which require suspension in the furnace. Chemical composition of the bars is: 0.17 to 0.20 C, 0.80 to 0.90 Mn, 0.17 to 0.22 Si, 0.040 S, 0.020 P, 0.12 Ni, 0.08 Cr, 0.02 Mo, 0.05 Cu, 0.15 total Ni plus Cu; all but the first three are maximum values.

The A.S.T.M. grain size is No. 1 to 4, with a maximum spread of two numbers. The test bars are run with the production parts in every furnace charge and at regular frequent intervals on continuous furnaces. Test bars which have been checked for case depth in the manner to be described are used to accept or reject production material with which they have been carburized. Use of test bars of uniform carburizing characteristics is necessary in order to isolate the variable being checked to that of the carburizing routine itself.

Hardening of Test Bars – After cooling from carburizing to at least a "black" heat, bars are loaded into a small Hevi-Duty electric furnace equipped with a circulating fan. Up to 20 pieces are loaded at one time in an alloy pan. This furnace is used for this work only and is maintained at 1440° F. ± 5° F. at all times. Heating time is held to 22 min. ± 30 sec., and no protective atmosphere is used. Test bars are then quenched until cold in a full flow of water at 75° F. ± 5° F.

Fracturing and Etching – The bars are broken transversely at approximately their midpoint and etched in 10% nital for 8 sec. Care must be exercised to use fresh nital which has not been exposed to air for more than 2 hr. The etched fracture is rinsed in water and dried with compressed air, resulting in a clear, definite line of demarcation between case and core.

Reading Case Depth – The instrument we developed for determining depth is of a simple, inexpensive design, yet it has eliminated the difference between individuals making the determination and the natural inclination of people to "interpret" the case measurement as they may happen to see fit. The principal parts of this instrument are an illuminated Bausch & Lomb Brinell microscope (magnification 10×),

Fig. 1 – Instrument Designed at Caterpillar Tractor Co. for Accurate Measurement of Case Depth. Principal parts consist of an illuminated Bausch and Lomb 10× Brinell microscope and a dial indicator mounted on a metal base. The case depth is read on the dial indicator

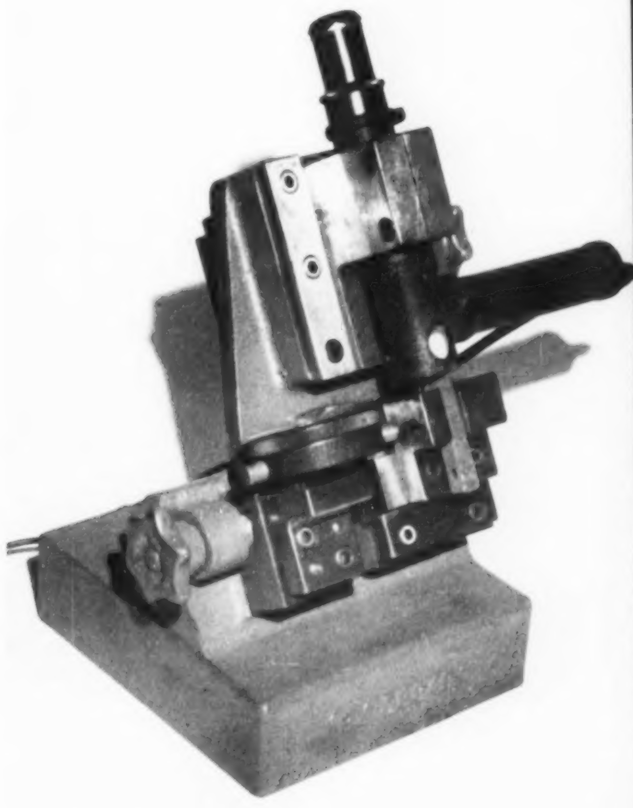


Fig. 2 – Rear View of Measuring Instrument With a Test Bar in Place

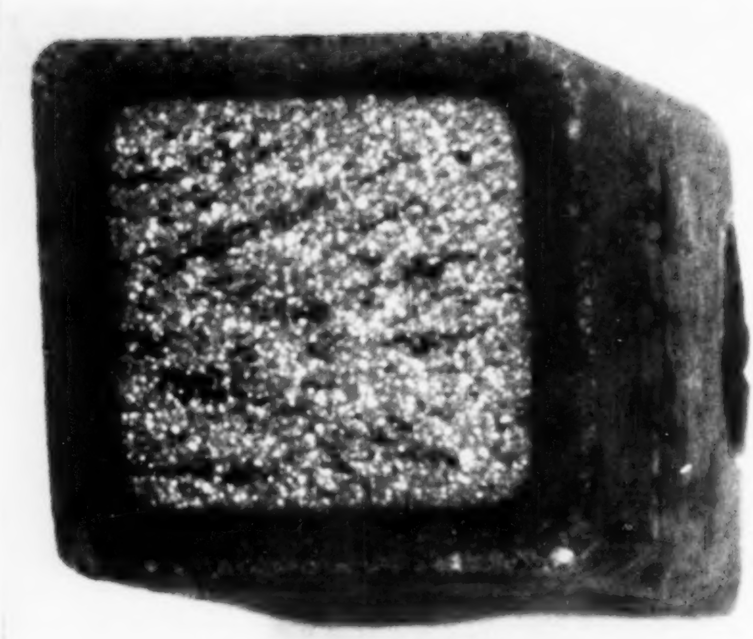


Fig. 3 – End View of Test Bar After Being Fractured and Etched. The case depth is clearly defined by the darker portion; free ferrite is indicated by the light spots in the center portion. 10×

and a dial indicator mounted on a metal base. When the test bar is placed in the instrument, the hairline of the microscope is zeroed to its edge. The bar is moved so that the hairline coincides with the first free ferrite. The case depth is then read directly on the dial indicator.

From our investigational work it was found that a reading to the first grain of free ferrite would coincide closely with a 0.40% carbon content and a hardness of Rockwell C-50. On this instrument accuracy of repetitive readings, between individuals as well as between different readings by the same individual, is within 0.001 in.

Figure 3 (reproduced at the same magnification the operator receives in the instrument) clearly shows the darker case depth.

It is recognized that the methods described in this article could not be applied to all shops as a means of production control, because some equipment is necessary, although it is by no means elaborate or expensive. However, it is with some hope of standardization that this description has been prepared, since there certainly is a need in industry for closer measurement as well as uniformity in methods employed. Perhaps variations from the foregoing would at least permit us all to "speak the same language" and make comparisons from the same basic beginning. If there were enough interest in standardization, it would not be difficult to make test bars and reading instruments available, just as standard methods and equipment for hardness measurements have been available for many years.

Current Russian Metallurgical

In continuation of the survey of contemporary Russian metallurgy, presented in the August 1951 and March 1953 issues of *Metal Progress*, five additional books published in the Soviet Union in the period 1947 to 1951 are here appraised. The first three are of special interest because they give a comprehensive and detailed description of both ferrous and nonferrous metals and alloys in production as of 1950-51. The other two are concerned with nonferrous industries, one extensively describing nickel and copper (a few critical issues excepted) and the other dabbling with a number of the so-called "rare metals", including molybdenum, titanium and the transuranics.

SOVIET METALS AND ALLOYS

"Introduction to Metallurgy," by G. I. Pogodin-Alekseev, Yu. A. Geller and A. G. Rakhshtadt; Governmental Publication for the War Industry, Moscow, 1950, 455 p.

Two Books on Corrosion

Texts—III

By CARL ANDREW ZAPFFE
Consulting Metallurgist
Baltimore, Md.

In considerable contrast to the usual "introductory" texts, this book contains information placing it in a class by itself. One of the better examples that might be mustered by a proponent of socialized science, it sets forth Soviet metallurgy from the organized viewpoint of a singular government-backed program. Significantly, the book is published by a governmental branch called the War Industry (more euphemistically named the "Ministry of Defense" in other countries), and its purpose is to serve as a uniform instruction on the properties and applications of standard metals and their alloys.

Even the introductory chapter is vigorous, compressing much information in brief compass. It is a history of Russian metallurgy beginning with Anasov in 1831, ending with Bochvar in 1947, and carrying 11 portraits of such distinguished investigators as Anasov, Tschernoff, Belyaev, Kurnakov, Baboshin, Shteinberg, and Bochvar—most of these also pretty well known to western scientists.

The remainder of the book is divided in six sections, plus an extensive appendix. The seven chapters of the first section describe methods for studying metals; binary and ternary diagrams are the subject of the second section; the third discusses plastic deformation and recrystallization; the next two treat the structure, properties, and heat treatment of both ferrous and nonferrous metals and alloys; and the sixth section closes with instructions for selecting the proper alloy and suitable heat treatment for a wide range of industrial and commercial applications.

Threaded throughout the entire text are 515 exemplary problems, designed to teach the students how to interpret the given theories and reduce them to practice.

The 56-page appendix lists by "mark", composition, and application all standardized metals and alloys used in the Soviet as of 1950—iron, steel, cast iron, copper-base alloys, aluminum-base alloys, magnesium alloys, bearing metals and babbitts, the hard metals (WC-TiC-Co combinations), and many others. The book offers an outstanding opportunity for comparing Russian and American ferrous and nonferrous practice.

"Metals and Alloys in Chemical Machine and Apparatus Construction," by D. O. Slavin and E. B. Shteiman; Government Scientific-Technical Publishing House, Moscow, 1951, 463 p.

In the preceding text, the Soviet standards are presented principally from the viewpoint of mechanical properties, whereas this second volume treats the same broad field principally from the standpoint of corrosion resistance. The two thus complement one another.

Introductory chapters contain many tabulations of corrosion measurements, based upon a "ball scale" rating of 1 to 10 covering 0.04 to 400 mils penetration per year. Electropolishing is discussed, a phosphoric acid electrolyte being recommended. There are charts for grain size, inclusion count, and graphite standards, this last with a discussion of spheroidal cast iron which appears in a Russian book for the first time, to this reviewer's knowledge.

As in Pogodin's text, a virtually complete listing of Soviet metals and alloys is given. A few differences between the two listings are apparently the result of a rapidly changing and improving system of codification, especially noticeable for high-alloy and stainless steels.

"Corrosion of Chemical Apparatus and Corrosion Resistant Materials," by I. Ya Klinov; Government Scientific-Technical Publishing House, Moscow, 1950, 291 p.

Although similar to the two preceding books, this text is inferior in both scope and detail. It specifically concerns special alloys designed for corrosion resistance, both in liquid mediums at ordinary temperatures and in active atmospheres at elevated temperatures. The treatment is at best mediocre—often either careless or uninformed—although some material can be found which supplements that in the other Russian texts.

Nonferrous Metals and Alloys

In the works of Slavin and of Pogodin-Alekseev and co-authors, the Soviet program for nonferrous metals and alloys is comprehensively outlined, whereas the two volumes next to be described treat certain of the nonferrous fields in more detail.

"The Metallurgy of Copper and Nickel," by V. I. Smirnov, Government Scientific-Technical Publishing House, Moscow, 1950, 591 p.

"In foreign countries the nickel industry provides a typical example from the Capitalistic Industrial Epoch of Imperialism and World Wars. Its growth proceeds irregularly, expressing those inevitable crises and depressions which step by step lead to the monopolizing of production."

Thus Smirnov comments upon the non-Soviet nickel industry in a brief introduction to what is otherwise an excellent technological discussion. His book is in two parts, one on copper, the other on nickel.

The Russian nickel industry is defined as entirely post-Revolution, except for primitive operations conducted in the Urals prior to 1917. An All-Soviet Conference for Nonferrous Metals was held early in Stalin's regime, and a plan was proposed for an organized nickel production based upon the Ufaleiski deposits in the Urals. By the time of the second conference, a specific program was formulated, using nickel oxide ores and bessemer matte. Later geological discoveries, in combination with the establishment of the Ufaleiski plants, led to a much broadened development which now includes a special institute for the study of nickel and related problems. Smirnov points to the present nickel industry as a proud example of Russian science and economy.

As for copper, he states that Russian production declined so badly during World War I that by 1918 it had virtually ceased. A tabulation of world production of cast copper is given, significantly subtitled "except U.S.S.R." A search of the text discloses only the indirect information that Soviet production during World War II was "many times greater" than in pre-Revolution years, and that the quota of the 1946-50 Five-Year Plan was exceeded by 160%. The total supply of copper in the various deposits of the world at the present time is estimated at 100 to 120 million tons, approximately 80% being in the U.S.S.R., Chile, Africa, and the U.S.A. Perhaps this can be interpolated by an expert to give a figure for Russian copper.

Smirnov states that Russia has rich deposits of copper ore in the Urals, Caucasus, and Siberia, and he names seven plants that have been built, but only for the period 1922 to 1931. Their augmented copper production is largely the result of the huge electrification program begun by Lenin at the Party's Annual Conference IX and culminated in Plan GOELRO. A significant part of Russian ores is porphyritic, but the carbonates malachite and azurite are also included, as well as the sulphides chalcocite, chalcopyrite, and bornite. Copper concentrates, Smirnov states, have been widely used since the first Five-Year Plan and today approximately 75% of Russian production is based upon concentrates.

Except for his careful omission of Russian production statistics, Smirnov makes free use of melting logs, balance sheets, heat calculations, and even photographs of Russian operations. No physical metallurgy is included, but as a treatment of process metallurgy for copper and nickel the book is above average.

"Rare Metals," by O. A. Songina, Government Scientific-Technical Publishing House, Moscow, 1951, 259 p.

One of the leanest of the texts yet reviewed – considering the opportunities offered by the subject of rare metals – Songina's volume is obviously a victim of wartime secrecy. Nine chapters treat W, Mo, V, Re, Nb, Ta, Ti, Zr, Hf, U, Th, Ce, Ga, In, Tl, Ge, Be, Li, Rb, and Cs in that order. The coverage is methodical, each chapter beginning with a more or less acceptable history, followed by discussions of physical and chemical properties, applications, minerals and ores, economics, extraction, production, and analysis. There are 219 references in a bibliography which has some internationalism, although the section on molybdenum, for example, is entirely Russian. A worth-while contribution is the section on beryllium, which discloses that beryl is the abundant and the principal beryllium ore used in Russia, and that electrolysis of fused chlorides is their accepted method of extraction – in contrast to American practice based on magnesium reduction of the fluoride. The Russian technology is given in detail. The chapter on uranium, as a contrasting example of barren sort, includes only an elementary description of nuclear processes and the production of transuranic elements up to californium, No. 98. Little is given on physical metallurgy in this book, attention being rather on the chemical technology of extraction, production and analysis.

By JOHN W. W. SULLIVAN
Metallurgical Engineer
American Iron and Steel Institute
New York City

Some Applications of Statistical Analysis in the Steel Industry

IN THE PREVIOUS three lectures in the Philadelphia Chapter's educational course on "Practical Applications of Statistics in Laboratory and Production" (published serially in *Metal Progress* since the September issue), Dr. Youden has already told how to measure the variations which exist in any group of ostensibly identical items caused by minor deviations in the materials, measurements and the measurers; next Professor Burr gave a brief account of methods, based on the mathematical theory of probabilities, of analyzing the data acquired from inspection and testing and for drawing useful conclusions therefrom; and then Mr. Hood outlined briefly ten ways wherein statistical methods are being used by the Aluminum Co. of America to help make a product of uniform and high enough quality to meet the requirements of use at the lowest possible cost.

In this, the final lecture, the control of variability in steel technology, on the basis of information revealed by statistical methods, will be discussed briefly by citing three case histories from many which are available. The wording of the last sentence has been chosen to emphasize the fact that statistical methods, by themselves, cannot control variability in steel technology. Statistical methods merely reveal significant numerical relationships, involving comparisons with standards. The actual control of variability is then accomplished by doing something or refraining from doing something to the raw materials, manufacturing operations and production personnel.

Variability is always present in manufacturing. No process, however skillfully controlled, can produce identical articles—that is to say, articles which cannot be distinguished from one another by measuring their properties.

A typical example of variability in the manufacture of alloy steel is shown in the black line of Fig. 1, already used by Professor Burr. It summarizes data from 331 heats of 4032 H steel (hardness of the Jominy bar, 1/16 in. from the quenched end). The smooth, bell-shaped curve superimposed in color is variously called the "normal curve", the "curve of error", the "probability curve" or the "population distribution", but by whatever name it is the limit that is approached by plotting a very large number of observations (or values of a variable). Its significance has been expounded in the previous lectures in this series; here it may be observed that statistical analysis of a limited set of data depends on the differences between the distribution of data from the sample and the normal probability curve.

The shape of the normal curve implies the following propositions, all of which have been verified experimentally:

Sources of Variability

1. Small deviations occur more frequently than large ones. This is mathematically verified by the fact that the curve has a maximum at the mean value.

2. Very large deviations are unlikely to occur since the curve is asymptotic with the X axis.

3. Positive and negative deviations of the same numerical magnitude are equally likely to occur since the curve is symmetrical with respect to the mean value.

The magnitude of the variation, together with the frequency or number of occurrences of variation (of the property values of successively produced articles) from particular or specified values, is what we are trying to control. Such variations in the finished articles, it is worthy of repeating, are due to

1. Variability in the raw materials used.
2. Variability in manufacturing operations.
3. Variability in the operating personnel.

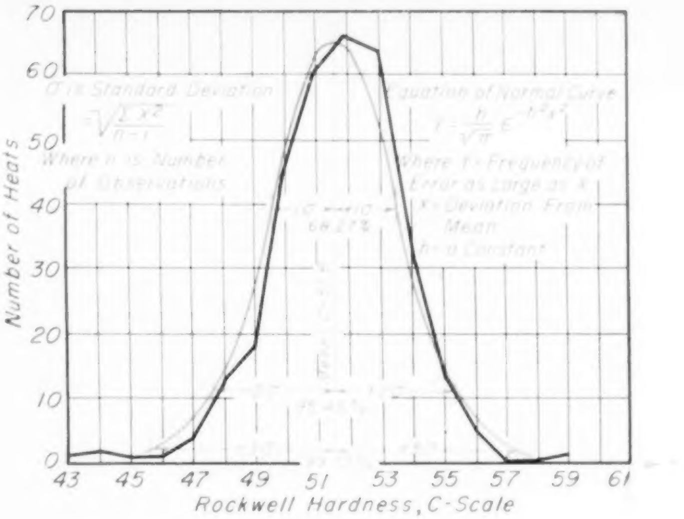


Fig. 1 – Frequency Polygon (Black Line) for Data on Hardness of 331 Heats of 4032 H Steel and (in Color) Normal Probability Curve for Indefinitely Large Number of Tests Which Would Have the Same Mean (51.6) and the Same Standard Deviation (2.08)

Fig. 2 – Exit End of 40-Wire Galvanizing Installation, Showing Sheaves Which Are Used for Carrying the Hot Wire Through a Water Quench. (Photograph courtesy of Republic Steel Corp.)

Let us now pass from these general and qualitative statements to some specific and quantitative case histories:

COATING ON GALVANIZED WIRE

Control of coating weight of hot-dipped galvanized steel wire by the aid of charts for "average" and "range" is an outstanding example of manufacturing variability control. Use of those charts resulted in a saving of 11.8% of zinc, with favorable prospects for more.

The problem concerned a 40-wire, hot-dip galvanizing unit in which steel wire in diameters of 0.072 to 0.162 in. can be coated with a specified minimum of 0.50 to 0.80 oz. of zinc per sq.ft. of surface. How should the process be operated to assure coatings of at least the specification minimum weight with a least consumption of zinc – that is to say, with the least surplus over the requirement? Incidentally, it required accurate measurements to 0.01 oz. per sq.ft., which, in terms of thickness of zinc coating is extremely thin – namely, 17 millionths of an inch.

Variations were measured by the first units described by Dr. Youden in the September 1953 issue of *Metal Progress*, namely "average" and "range". (The charts and methods are completely described on p. 290 to 320 of Walter A. Shewhart's book "Economic Control of Quality of Manufactured Product", published by Van Nostrand, New York, in 1931, and in the A.S.T.M.'s "Manual on Presentation of Data", 1940, p. 47 to 66.) Briefly stated, controlling the average and the range of variability is based on the concept that a process is in "statistical control" – with respect to a particular property of the process or the product – when the property values are within the control limits on the charts. The control limits are related to the range of variability that can be expected when no significant changes occur in the raw materials, manufacturing operations and operating workmen; theoretically, the variability in the process and the product is then due solely to chance and consequently the range of variability is predictable.

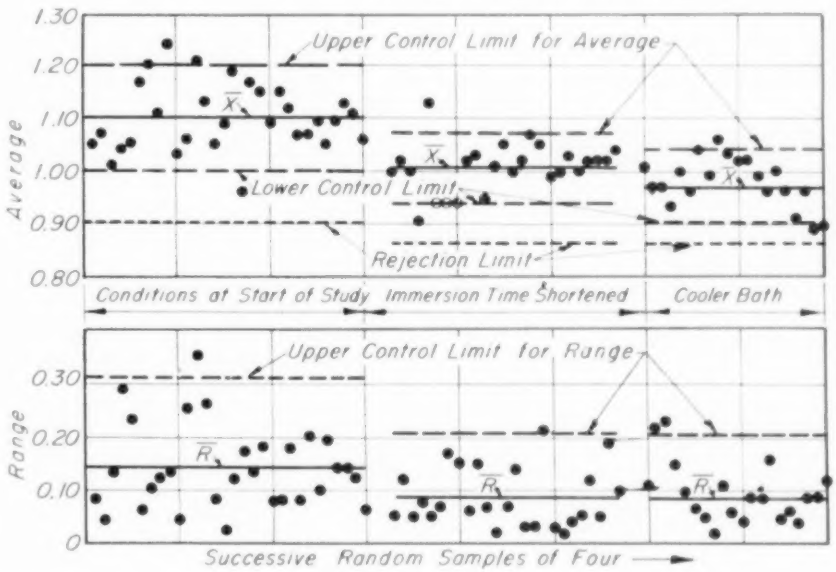
When property values are observed which are *outside* the predicted range, the probability that they resulted from a process in statistical control (as well as the probability that they resulted from a process *not* in statistical control) can be computed. Those probabilities are the primary guides in deciding whether or not a variation in a property value from a predetermined reference value or standard is an important variation which necessitates a change in the process, or, on the contrary, is an unimportant variation not requiring a change to maintain the process within the desired control limits.

The charts for average and range of coating weight of galvanized wire, which we are about to discuss in detail, are shown in Fig. 3.

The left portion of Fig. 3 shows two control charts during the first stage of the investigation, the upper being the chart for average coating weight and the lower the chart for range of the coating weights.

The chart for average was prepared in the following manner: Four of the 40 galvanized wires were selected at random to provide a sample of four pieces, and the weight of the zinc coating on each was determined in oz. per sq.ft. The average of the four results was plotted as a single dot on the upper chart. Periodically, successive samples of four pieces each were taken, the coating weights determined and averaged,

Fig. 3—Control Charts for Average Weight of Zinc Coating on Hot-Dip Galvanized Wire, and for Range of Weight. Size 0.105-in. extra galvanized wire, specified to have 0.80 oz. per sq.ft. minimum of zinc



and the average plotted in succession. After the production of a predetermined amount of wire, and the plotting of a predetermined number of averages of coating weights, the arithmetical average of the averages was computed. It turned out to be 1.10 oz. per sq.ft., and this is represented by $\bar{\bar{x}}$, the central horizontal line in the upper chart in Fig. 3.

The dashed horizontal lines in the left portion of the top chart are the upper control limit for average (UCL) and the lower control limit for average (LCL) respectively, and their values are computed to be 1.20 and 1.00 oz. per sq.ft. from the formulas

$$UCL = \bar{\bar{x}} + c\,\bar{R}$$
$$LCL = \bar{\bar{x}} - c\,\bar{R}$$

where $\bar{\bar{x}}$ is the grand average (average of the individual averages) and $\bar{R}$ is the average of the individual ranges shown in Fig. 3 and c is a constant depending on sample size, being 0.729 for a sample of four.

The range of variability in coating weight, plotted in the lower part of the chart, is numerically equal to the difference between the maximum and minimum of each sample of four. That range is plotted for each of the samples, directly below the corresponding plotted value for the average. The average range, $\bar{R}$, obtained by summing the range values and dividing by the number of samples, is plotted as the central line in the lower chart. The upper control limit for range is computed by multiplying the average range by a constant which depends upon the sample size. For a sample size of four the constant is 2.28. The lower control limit for range is plotted only when the sample size exceeds six, because the lower control limit is zero for sample sizes of six or less. In the left portion of the lower chart in Fig. 3 the average of the range is 0.138 oz. per sq.ft. and the upper control limit for range is 0.314 oz. per sq.ft.

The 30 values plotted in the left portion of Fig. 3, although limited in number, suggest that the process is practically in statistical control – that is, the variability in the weight of the zinc coating as expressed by the control limits is the result of chance variations in the process. However, the grand average ($\bar{\bar{x}}$ = 1.10 oz. per sq.ft.) is higher than is desired for a specification minimum of 0.80 oz. per sq.ft. Consequently, a change was made in the process that was intended to lower the grand average and yet control the variability so that the specified minimum would be met. That change was a decrease in the time of the immersion of the wire in molten zinc. Actually, that change involved two variables – the length of the immersion and the speed of the wire – since neither could be changed independently because they are both related to the mechanical properties of the wire and to the properties of the coating. Both were changed in such a manner as to reduce the immersion time and not significantly change the mechanical properties. The results of that change in practice are shown in the center portion of Fig. 3.

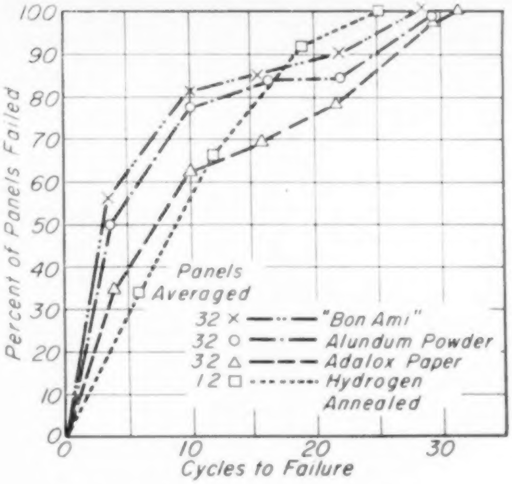


Fig. 4 – Preliminary Tests on Oiled Sheet Steel in Humidity Cabinet, Operated Cyclically, Show Uncontrolled Variability in Test Conditions, Since "Cycles to Failure" Vary by More Than 100%

Two improvements resulted – a reduction in the grand average from 1.10 to 1.007 oz. per sq.ft. and a reduction in the variability, as expressed by the difference in the control limits for average, from 0.20 to 0.133 oz. per sq.ft.

At this point the metallurgist responsible for the development of the control charts decided to make another change in the process to reduce further the consumption of zinc and still produce an acceptable product. The bath temperature was lowered with results shown in the right portion of Fig. 3.

The grand average, or "level" of the process, was lowered to 0.97 oz. per sq.ft. The variability (difference between upper and lower control limits) remained about the same, namely 0.14. At this point it was found that the process was operating at a saving of 11.8% of the zinc and was producing an acceptable product.

Although the specification minimum of 0.80 is appreciably below the lower control limit of

0.90, a "modified lower control limit" of 0.87 oz. per sq.ft. was drawn on the upper chart in the right portion of Fig. 3 as a rejection limit. That limit corresponds to the specification minimum plus half the allowable deviation of the averages.

Other data, not shown in this case history, suggest that there is at least one additional variable which affects the coating weight, and a search for that variable is now in progress, so that even greater saving in zinc may result from the use of the foregoing control chart method of controlling variability.*

A STUDY OF A TEST METHOD

Protection of steel from rusting while in transit to a fabricating plant or warehouse is currently under investigation by the Technical Committee on Protective Coatings of the American Iron and Steel Institute by accelerated testing of steel panels coated with protective oils. Such a test program involves a study of the variable protection offered by specific oils, and is complicated at least by two additional sources of variability, namely, the testing apparatus itself and the steel surface immediately prior to coating.

The testing apparatus is essentially a humidity cabinet in which the humidity, temperature, flow of air, cleanliness of the air and inertness of specimen holders are controlled to a degree believed to be adequate. However, the cabinet exhibited variability traceable to at least one cause, the position of the specimens in the cabinet, and possibly to other causes.

At the start of the investigation, steel panels were cut from one grade of sheet steel having a particular and reproducible surface finish, made to conventional standards. This finish was believed to be sufficiently uniform to rule out any significant variability from that source, but it turned out to be insufficiently uniform, possibly because of variability occurring in the superficial oxide film.

The initial search for a method of providing a uniform steel surface, to rule out the surface as a significant source of variability, was disappointing. Figure 4 shows the results of polishing the steel surface with various abrasives and also the results of reducing the oxide coating by hydrogen.

For each type of finish the number of humidity cycles to failure of a given oil film varied from less than 10 to more than 20, or a difference of more than 100%, despite efforts to control every other known source of variability. However, the search continues, and the latest reports on the development of a new surface treatment are encouraging.

Another important factor in this investigation turned out to be a method of applying the protective oil so as to yield a uniform and reproducible film having a closely controlled thickness. It was found that apparently identical oil films behaved differently, possibly because polar compounds in the oil were not uniformly distributed throughout the film or did not uniformly cling to the surface of the panels.

Thus, the test results are a summation or integration of all of the sources of variability (both known and unknown) in the testing of the oils. Fortunately, however, statistical methods known as "variance analysis" are now being used to separate known sources of variability from each other. This statistical method of evaluation involves the calculation of the standard errors of successive runs and of the differences between means, and also the testing of those differences for significance.

When the statistical analysis is completed it is likely that quantitative explanations will be available to account at least for some of the known sources of variability.† Of greater importance, however, will be some quantitative measure of the range of variability of test results that can be attributed to the oil protective coatings themselves, independently of other sources of variability. In this way, it is expected that ultimately the accelerated testing of the coatings can be placed on a more reliable basis.

Problems of the foregoing type, involving complex interactions of causes of variability, can be successfully analyzed today only by statistical methods. This matter was discussed in some

*In the discussion, a questioner raised the point that "in the inspection of a coil of wire for defects there is not a coil at the finish but several pieces". However, a coiled wire has two ends. If it is a matter of dimensional control, a measurement of both ends usually gives satisfactory assurance as to the dimensions throughout the length of the coil. By checking the diameter of the wire at periodic intervals, changes in dimension resulting from tool wear can be detected so that it is possible to control the process without the necessity for destroying individual coils. There may be intermittent defects throughout a coil of wire — or for that matter in a coil of sheet or a coil of foil — which cannot be detected by inspection of the ends. Necessarily reliance must then be placed on either the inspection of a great many ends of the product, or intermediate inspection during the final shearing or coiling operations, or by correlating the results obtained in subsequent operations in the customer's plant where the material is cut into smaller pieces.

†See "Analysis of Variability in Accelerated Corrosion Testing Cabinets", by V. V. Kendall, *Yearbook* of the American Iron and Steel Institute, 1953.

Determination of Hardenability Bands

detail by Professor Burr in his lecture published in October's *Metal Progress*.*

In view of the widespread use in America of alloy steels purchased to hardenability limits as measured by the Jominy end-quench test, it may be of more than ordinary interest to review the manner in which statistical studies have aided in fixing the commercial limits in existing specifications. This brief account will concern the steel used during the war and designated as 4032 H with approximately 0.25% molybdenum. It is a carburizing steel, used for transmission gears and pinions for passenger automobiles, and light gears for trucks.

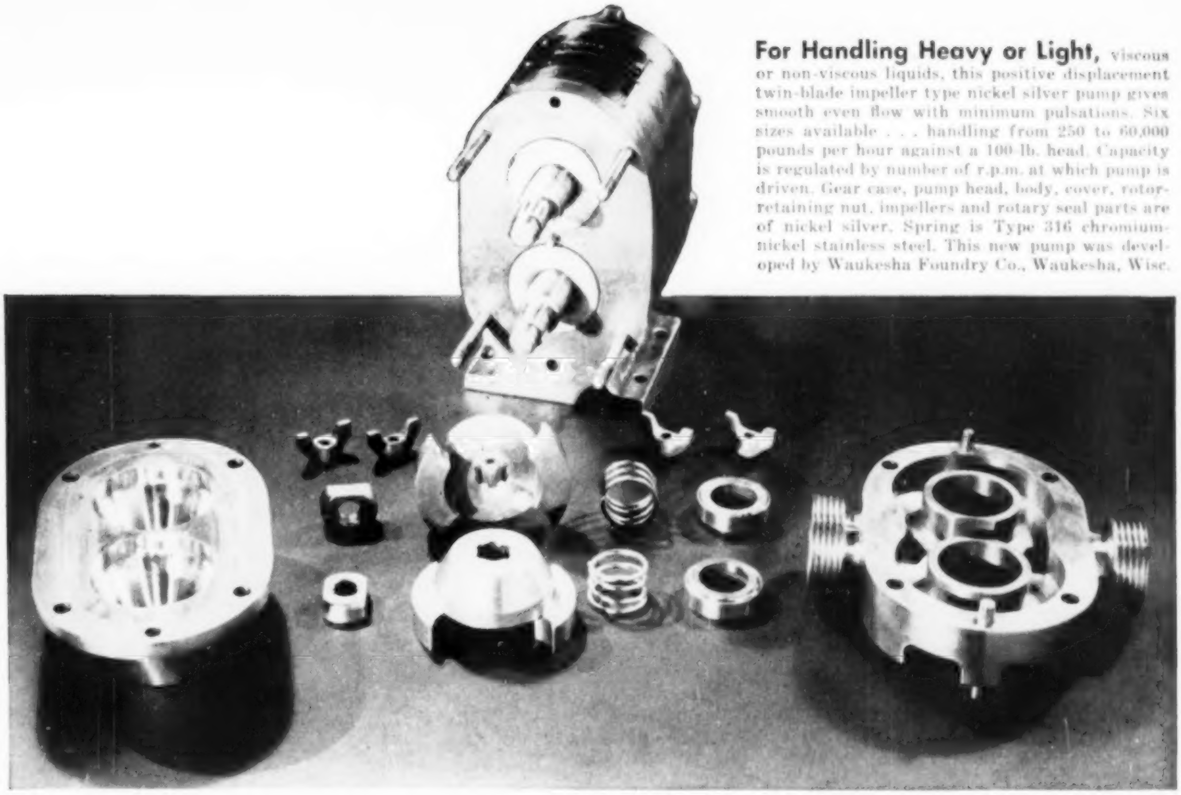
The statistical phase of the problem confronting the steel industry was to determine the hardness limits narrow enough so the steel could be heat treated to a satisfactorily uniform product in mass production, and also be within the economical limits of manufacture – despite the variability in steelmaking practices that existed from company to company, plant to plant within a company, and furnace to furnace within a plant – to say nothing of the wide variability in scrap, fuel and other materials in the furnaces owing to geographical location of the plants.

Establishment of specified limits is desirable because a single consumer demands from several producers the identical steel so far as hardenability limits are concerned. The consumer wants identical steel from various sources so that he does not have to vary his heat treating medium and procedure. In effect, the steel producers aid the consumer by providing a narrow range of hardenability variability.

Prior to the 1930-1940 decade the word "hardenability" was usable only in a qualitative sense. Since then quantitative bases have been established from the work of the late Marcus A. Grossmann and of W. E. Jominy and A. L. Boegehold. That work is so well known to members of the American Society for Metals that it would be superfluous to outline its nature and great influence on modern steel treatment. Suffice it to say that prior to their studies the steel industry and its demanding customers attempted to control hardenability by narrowing the ranges for the individual elements in the steel.

John W. W. Sullivan, since 1945 with the technical staff of the American Iron and Steel Institute, and now its metallurgical engineer in New York City, has held positions as research engineer with A. O. Smith Corp. in Milwaukee, and a similar post with the American Steel & Wire Co. in Cleveland. During World War II he was chief of inspection for the Cleveland Ordnance District. He has also written on science subjects for the Cleveland Plain Dealer, *and is the author of the ⊕'s best selling techbook "The Story of Metals". Among others, he is a member of the American Society for Metals, the American Institute of Mining and Metallurgical Engineers, the American Society for Quality Control, and the American Statistical Association.*

*A shrewd way of applying "variance analysis" was quoted from a scheme used by Richard Ede of the Gary plant of U. S. Steel Corp. His technique may be illustrated from a study of the effect of composition on a certain property of steel. Assuming the sulphur content is an important factor and that it is slightly "out of control", the midpoint of all the sulphur figures is determined. About half the heats of this type will have sulphur higher than this value, and half will be lower, but the data themselves will set that point. Then he'll say it's "high sulphur" above this point, and "low sulphur" below it. (Or one can break up all the sulphur data that you have on, say 706 heats, into three parts substantially equal.) Then he'll do the same thing with manganese, thus getting two or three levels of manganese – again, letting the data decide where the group is subdivided. Then he does the same thing with the third factor. That gives him roughly the same number of measurements in each cell, or at least a fair number in each. Then what he does is find out which cell has the least number in it, and pick at random that many from all the data you have for each of the rest of the cells. That gives a "factorial design", and is an automatic way of taking these heterogeneous industrial data from observers' records and putting them together to make a good analysis in a very little time.



For Handling Heavy or Light, viscous or non-viscous liquids, this positive displacement twin-blade impeller type nickel silver pump gives smooth even flow with minimum pulsations. Six sizes available . . . handling from 250 to 60,000 pounds per hour against a 100-lb. head. Capacity is regulated by number of r.p.m. at which pump is driven. Gear case, pump head, body, cover, rotor-retaining nut, impellers and rotary seal parts are of nickel silver. Spring is Type 316 chromium-nickel stainless steel. This new pump was developed by Waukesha Foundry Co., Waukesha, Wisc.

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Solid white metal all the way through, nickel silvers usually provide greater strength and corrosion-resistance than do ordinary brasses and bronzes.

Wrought or cast, the impressive beauty and moderate cost of nickel silvers . . . plus their ready response to fabrication by ordinary methods . . . make these alloys particularly useful for improving both quality and quantity of output.

Gain competitive advantages by using these alloys. The several grades of nickel silvers permit selecting one with the best set of properties for any reasonable fabrication and service demands. We shall be glad to furnish you with counsel and data on these versatile alloys.

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Aluminum Sand Casting Alloys

Compositions, Properties, and Designations of American Commercial Alloys

Compiled by F. M. Howell, Aluminum Co. of America, and H. S. Jerabek, University of Minnesota, November 1953, from handbooks and specifications of the principal manufacturers, the American Society for Testing Materials and the Society of Automotive Engineers.

Designations			Composition (Balance is Aluminum)					Condition	Tensile Strength (a)		Yield Strength (a)	Elongation % in 2 In.		Brinell Hardness	Shear Strength (a)	Endurance Limit (a, c)	Fluidity (d)	Pressure Tightness (d)	Resistance to Hot Cracking (d)	Corrosion Resistance (d, m)	Machinability (d)	Ease of Welding (d)	Characteristics and Uses
S.A.E. No.	A.S.T.M. Spec. B 26	Alcoa No.*	Cu	Si	Mg	Zn	Other		Av.	Min.	Av.	Av.	Min.										
33	CS 72 A	113-F	7.0	2.0		1.7		As Cast	24	19	15	1.5	(e)	70	20	9	B	C +	C	D	B	C	General-purpose casting alloys with similar properties.
		212-F	8.0	1.2				As Cast	23	19	14	2.0	(e)	65	20	9	B	C	C	D	B	C	113 having improved casting characteristics.
		112-F	7.0			1.7		As Cast	24	19	15	1.5	(e)	70	20	9	B	C	D	D	B	C	Crankcases, gear housings, cover plates.
	CS 43 A	108-F	4.0	3.0				As Cast	21	19	14	2.5	1.5	55	17	11	B	B	B	D	C	B	Good casting properties, pressure tightness; manifolds.
35	S 5 A, B	43-F		5.0				As Cast	19	17	8	8	3.0	40	14	8	A	A	A	B	E	A	Excellent castability, pressure tightness, corrosion resistance.
310	ZG 61 A			(0.2 Ti)	0.6	5.6	0.5 Cr	Aged Only		32	25		3.0				D	C	E	B	A	D	These alloys are similar in properties and characteristics;
	ZG 61 B	A 612-F	0.5		0.7	6.5		As Cast	35 (h)	32 (k)	25 (h)	5 (h)	2 (k)	75 (h)		8	D	C	E	B	A	D	they develop high strength on aging for 4 weeks
	ZG 42 A			(0.5 Mn)	2.1	4.2	0.3 Cr	Aged Only		33	22 (b)		2.0				D	C	E	B	A	D	without heat treatment, have good ductility, excellent
	ZG 32 A			(0.5 Mn)	1.6	3.0	0.3 Cr	Aged Only		30	17 (b)		5.0				D	C	E	B	A	D	machinability, fair casting properties and are suitable
	ZC 81 A		0.7		0.4	7.5		Aged Only		30	22 (b)		3.0				D	C	E	B	A	D	for brazing; general-purpose alloys.
320	G 4 A	214-F			3.8			As Cast	25	22	12	9.0	6.0	50	20	7	E	E	D	A	A	D	Excellent corrosion and tarnish resistance;
	GS 42 A	B 214-F		1.8	3.8			As Cast	20	17	13	2.0	(e)	50	17		C	D	C	A	B	D	silicon in B 214-F improves casting properties at expense of some strength and response to anodizing.
		F 214-F		0.5	3.8			As Cast	21	17	12	3.0	(e)	50	17		C	D	C	A	B	D	
38	C 4 A	195-T 4 (g)	4.5					Soln. H.T. (n)	32	29	16	8.5	6.0	60	26	7	C	D	D	C	C	C	High-strength alloy used in heat treated condition;
		195-T 6	4.5					H.T. & Aged (p)	36	32	24	5.0	3.0	75	30	7.5	C	D	D	C	B	C	only fair casting properties, good machinability; useful
		195-T 62	4.5					H.T. & Aged (p)	40	36	34	1.5	(e)	95	32	8	C	D	D	C	B	C	for stressed housings, crankcase and aircraft parts.
322	SC 51 A	355-T 51	1.3	5.0	0.5			Aged Only	28	25	23	1.5	(e)	65	22	7	A	A	A	B –	C	B	Excellent casting properties and pressure tightness,
		355-T 6	1.3	5.0	0.5			H.T. & Aged (p)	35	32	25	3.0	2.0	80	28	9	A	A	A	B –	C	B	good corrosion resistance and weldability, fair
		355-T 61	1.3	5.0	0.5			H.T. & Aged (p)	39	36	35	1.0	(e)	90	31	9.5	A	A	A	B –	C	B	machinability; air compressor pistons, water-cooled
		355-T 7	1.3	5.0	0.5			H.T. & Aged (p)	38	35	36	0.5	(e)	85	28	10	A	A	A	B –	C	B	cylinder heads, blower rotors, gear housings, crankcases,
		355-T 71	1.3	5.0	0.5			H.T. & Aged (p)	35	30	29	1.5	(e)	75	26	10	A	A	A	B –	C	B	printing press bed plates.
323	SG 70 A	356-T 51		7.0	0.3			Aged Only	25	23	20	2.0	(e)	60	20	7.5	A	A	A	B	D	B	Similar to S.A.E. 322; poor machinability; excellent
		356-T 6		7.0	0.3			H.T. & Aged (p)	33	30	24	3.5	3.0	70	26	8.5	A	A	A	B	D	B	casting properties, good weldability and corrosion
		356-T 7		7.0	0.3			H.T. & Aged (p)	34	31	30	2.0	(e)	75	24	9	A	A	A	B	D	B	resistance; useful for transmission cases, flywheel
		356-T 71		7.0	0.3			H.T. & Aged (p)	28	25	21	3.5	3.0	60	20		A	A	A	B	D	B	housings, oil pans, aircraft fittings and control parts.
327	SC 82 A		1.5	7.8	0.4		0.4 Mn	H.T. & Aged		34			1.0				A	A	A	C	D	B	Similar to S.A.E. 322.
329	SC 64 C	319-F	3.5	6.3				As Cast	27	23	18	2.0	(e)	70	22	10	B	B	B	D	D	B	Very good casting and mechanical properties; useful for
	SC 64 C	319-T 6	3.5	6.3				H.T. & Aged (p)	36	31	24	2.0	1.5	80	29	10	B	B	B	C	C	B	piano plates and frames, crankcases, housings.
326	SC 64 B		3.8	6.3				H.T. & Aged (p)		32	23		2.5				B	B	B	C	C	B	Similar to S.A.E. 329.
34	CG 100 A	122-T 61	10.0		0.2			H.T. & Aged (p)	41	30	40	(f)	(e)	115	32	8.5	C	C	C	D	A	D	Good hardness, wear resistance, high-temperature strength.
39	CN 42 A	142-T 21	4.0		1.5		2 Ni	Annealed	27	23	18	1.0	(e)	70	21	6.5	C	C	D	C	C	D	Good strength at elevated temperatures, good bearing
		142-T 571	4.0		1.5		2 Ni	Aged Only	32	29	30	0.5	(e)	85	26		C	C	D	C	B	D	characteristics; useful for air-cooled cylinder heads, diesel
		142-T 77	4.0		1.5		2 Ni	H.T. & Aged (p)	30	21.5	23	2.0	(e)	75	24	10.5	C	C	D	C	B	D	engine pistons.
324	G 10 A	220-T 4			10			Sol. H.T. (n)	46	42	25	14	12	75	33	8	C	D	B	A	A	E	Highest strength, elongation and shock resistance for aircraft parts; requires special foundry practices.

* Aluminum Co. of America alloy numbers. Heat treated alloys designated by letter T and heat treatment number after alloy number.

(a) In thousands of pounds per square inch.

(b) Minimum values.

(c) 500 million cycles in reverse bending using R. R. Moore machine and specimen.

(d) Relative rating; A = best.

(e) Not required. Experimental error comparable with values being measured when below 1% elongation.

(f) Less than 0.5%.

(g) After standing at room temperature for several weeks the properties will approach those of the T 6 condition.

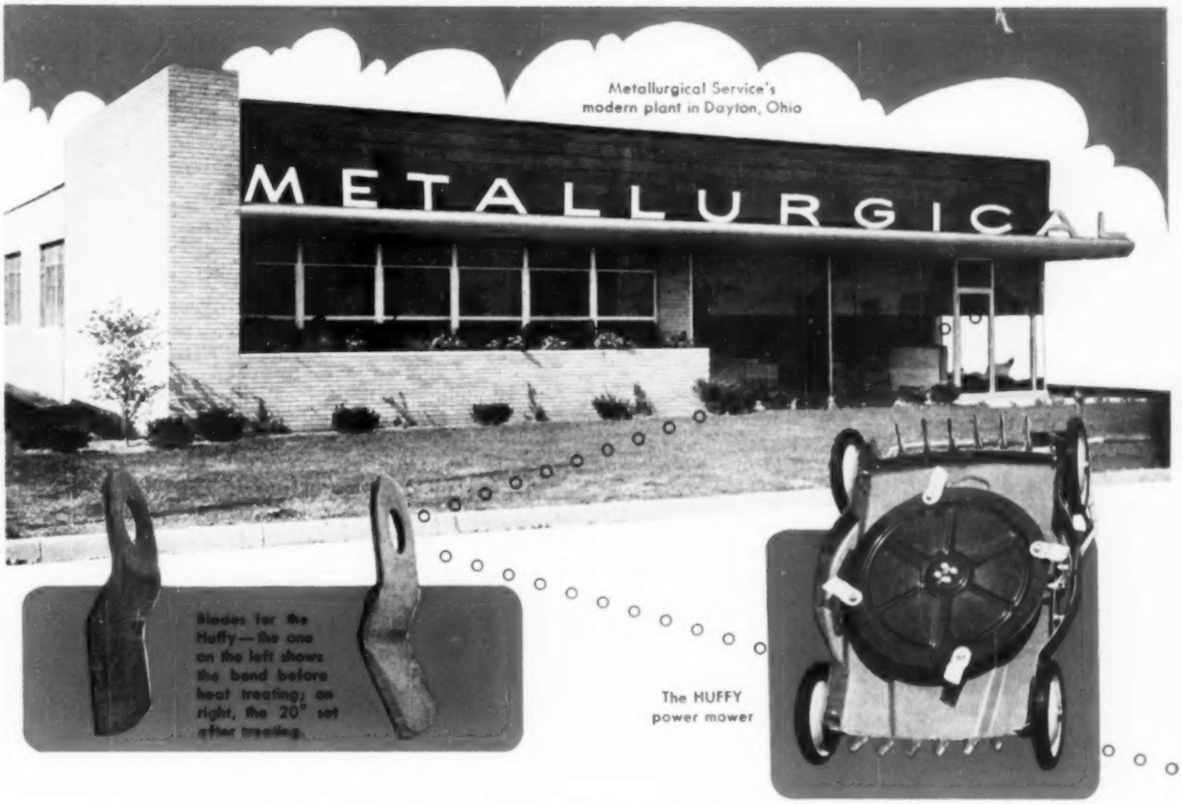
(h) From tests made approximately 30 days after casting.

(k) Based on tests made 5 to 7 days after casting.

(m) Relative corrosion resistance, as in marine exposure.

(n) Solution heat treatment involves soaking at high temperature followed by quenching.

(p) Solution heat treatment, followed by artificial aging above room temperature.



Metallurgical Service meets tough specs for Huffman mower blades with AEROHEAT® 1000 and AEROHEAT® 300 Heat Treating Compounds

Huffman Manufacturing Company of Dayton, Ohio, makes the HUFFY line of electric and gasoline power mowers. Four blades like those illustrated are used in each mower.

Here are their blade specifications—rigid ones that are checked statistically for each batch of blades:

1. Hardness—uniform 48-52 Rockwell C
2. Bend—blades must take a 20° set, which means they must be bent to about 30°
3. Peening—there must be no evidence of radial cracking after a two-pound weight drops three feet onto the cutting edge.

Metallurgical Service Inc., austempers these tool steel analysis blades at their modern Dayton plant using AEROHEAT 1000 and quenching them into AEROHEAT 300. The high stability of AEROHEAT 1000 combined with the excellent quenching power of AEROHEAT 300—plus careful handling of a tricky job—permits Metallurgical Service to meet their customer's exacting requirements. Why not get the details on AEROHEAT 1000 and AEROHEAT 300? They may help you with your heat treating problems.

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☐ Send data sheets on AEROHEAT 1000 and AEROHEAT 300
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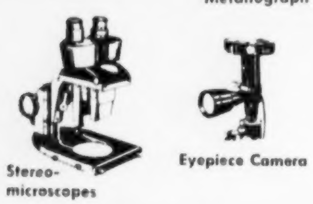
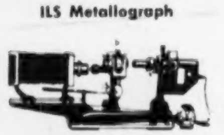


Research Metallograph

ILS Metallograph



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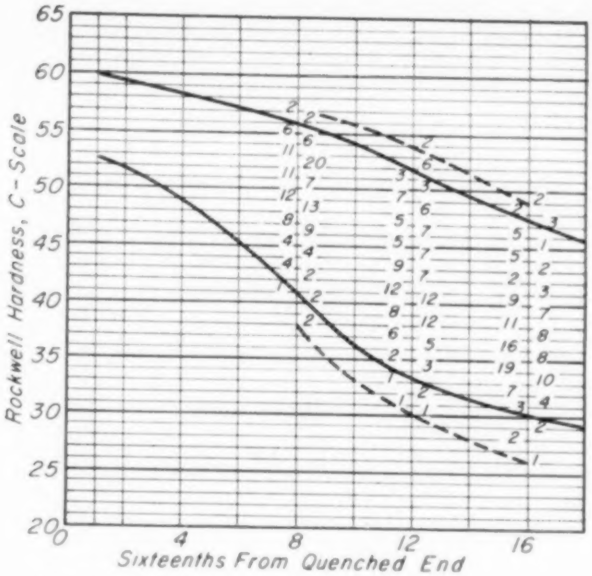


Fig. 5 — Distribution of Hardness Readings on Jominy End-Quench Bars From 126 Heats of 3140 H at 8, 12 and 16 Sixteenths From the Quenched End. About 7% of the heats fall outside the accepted band

such as carbon, manganese, nickel, chromium and molybdenum, and this resulted in A.I.S.I.-S.A.E. specifications for alloy steel having very narrow ranges in composition. Such narrow ranges were not the solution of the problem because studies made in 1943 and again in 1946 and 1947 revealed that 14 to 16% of the open-hearth alloy steel fell outside the established standard chemical ranges, yet many of these out-of-specification heats were accepted upon submission to the user and performed satisfactorily. Narrow limits did not control the hardenability, nor did supplementary requirements such as grain size limitations, tensile properties, special hardening tests and others which were added to some customers' specifications. How this situation was corrected by the use of end-quench tests and hardenability bands permitting considerably wider chemical limits is considered at some length in a paper entitled "Standard Steels and H-Band Steels" by D. H. Ruhnke, E. T. Walton and P. R. Wray before the 1948 regional technical meetings of the American Iron and Steel Institute.

The first published hardenability bands were established with the aid of a calculation method suggested by Grossmann and were converted to hardness curves. The band within the curves included approximately 93% of the hardness results, and the curves were adjusted by comparison with actual end-quench tests from production heats. Because of occasional deviations from reality in calculating hardenability from chemical compositon and grain size, hardenability bands established since 1947 are based on statistical studies of actual end-quench hardenability tests from hundreds of production heats. An early example is Fig. 5, which shows a portion of the hardenability band for 3140 H.

The numbers listed vertically through the band show the number of heats whose hardness corresponded to that particular ordinate, and they comprise the hardness distribution at a particular distance from the quenched end. The curves defining the band were drawn after approximately 3½% of the heats having the highest hardenability and a like percentage having the lowest hardenability were discarded. In this way the user is protected from receiving the occasional heat of steel that might crack on account of excessive hardenability and also on account of the occasional heat so low in hardenability that the steel might not harden properly or might require special processing.

A much better way of appraising an observed hardness distribution is illustrated in the data of Table I, taken from that used in 1950 for establishing the hardenability band limits for grade 4032 H and derived from end-quench hardenability tests of 331 heats.

Since these figures, representing hardness values at 4/16 in. from the quenched end of the specimen, have been analyzed previously in Professor Burr's lecture (*Metal Progress*, September), and the analysis summarized in Fig. 1, p. 92 of the present article, it need only be repeated that the mean value is hardness 51.65 and the standard deviation (a measure of the variability) is 2.08 units. The actual range of observed values at this particular location in the test piece is from a low of C-43 to a high of C-59, or 16 units.

Nearly all of the total area under the normal curve (the curve in color in Fig. 1) lies between the limits of the average plus and minus three standard deviations, the precise amount being 99.73% to the fourth significant figure. This is an important statistical concept because it means that 99.73% of the values should lie between the limits of plus and minus three standard deviations from the average, provided the manufacturing process is under control.

Plotting Impurity Effects

Hence, if any values lie beyond those limits the theoretical chance of those values occurring when the process is in control is only 27 in 10,000 or approximately 3 in 1000; conversely, the chances are great that such values result from a process out of control.

Applying the foregoing statistical concept to the Rockwell C-scale hardness obtained at a distance of 1/16 in. from the quenched end of the specimen for the 331 heats of grade 4032 H, we find that the limits of the average plus and minus three standard deviations are 45.41 to 57.89. Within those limits there are 327 hardness values, or 98.8% of the heats. Only four heats out of 331 are outside those limits. In view of the theoretical percentage of 99.73 it would appear that the manufacturing process is in control or extremely close.

Table I — Quenched Hardness of 331 Heats of 4032H and Computation of Variability (Sullivan)

Rockwell Hardness	Number of Heats	Difference From Mean	$n x^2$	
C-59	1	+7.4	$1 \times 7.4^2 =$	54.76
58	0	—		—
57	0	—		—
56	5	+4.4	$5 \times 4.4^2 =$	96.80
55	14	+3.4	$14 \times 3.4^2 =$	161.84
54	34	+2.4	$34 \times 2.4^2 =$	195.84
53	64	+1.4	$64 \times 1.4^2 =$	125.44
52	66	+0.4	$66 \times 0.4^2 =$	10.56
51	61	−0.6	$61 \times 0.6^2 =$	21.96
50	46	−1.6	$46 \times 1.6^2 =$	117.76
49	18	−2.6	$18 \times 2.6^2 =$	121.68
48	13	−3.6	$13 \times 3.6^2 =$	168.48
47	4	−4.6	$4 \times 4.6^2 =$	84.64
46	1	−5.6	$1 \times 5.6^2 =$	31.36
45	1	−6.6	$1 \times 6.6^2 =$	43.56
44	2	−7.6	$2 \times 7.6^2 =$	115.52
43	1	−8.6	$1 \times 8.6^2 =$	73.96
	331		$\Sigma(\times)^2 =$	1424.16

Range C-43 to C-59
Median value C-52
Arithmetical mean C-51.6

Standard deviation $\rho = \sqrt{\frac{\Sigma \times^2}{n-1}} = \sqrt{\frac{1424.16}{330}} = 2.08$

To provide a margin of safety, for heats that may be slightly too high or too low in hardenability, the hardenability limits for grade 4032 H were set inside the three standard deviations at 48 and 55.5. This corresponds to a range of approximately plus and minus two standard deviations from the arithmetical mean.

The limits 48 to 55.5 embrace 316 heats or 95.5% of the total. The theoretical percentage of values within the average plus and minus two standard deviations is 95.45. This does not necessarily mean that the entire band including all distances from the quenched end of the specimen was established on this basis, but it does indicate that the quality of the product is assured in any manufacturing process, when the variability can be consistently and economically controlled at levels within those of the average plus and minus three standard deviations.

The foregoing case history (and others) certifies to the fact that the properties of a particular grade of steel produced by different companies are so uniform that the steels are interchangeable in use and are often indistinguishable by ordinary laboratory tests.

Incidental Impurities – Sometimes an almost impossible set of variables can be handled by subdividing the lot into manageable groups. An example is a study of the effect of ten incidental elements on the properties of carbon steel plate made by three refining processes. This involved 13 variables for each thickness. Solution of 13 simultaneous equations relating yield strength (or tensile strength) to these variables as determined for 145 heats of steel would require about 20 hr. by the calculating machine at Harvard University, or 800 hr. if manually computed. This for each property for each thickness.

Faced by this formidable situation, 35 heats were selected, all made from semikilled steel and rolled into ½-in. plate. Yield strength at room temperature was plotted against variability in manganese content between 0.39 and 0.59%, carbon content between 0.10 and 0.26%, copper content between 0.20 and 0.30% and so on. A review of these charts showed that such incidental variation did not lower the property; any change was in the direction of a slight improvement. Similarly, charts plotting other properties against composition showed no detriment in strength or ductility at room temperature or at 400, 600, 800 and 1000° F.

In summary, it is hoped that variability has been described and identified in a few problems of wire production, corrosion test development, and hardenability evaluation. Some case histories have been detailed to reveal some of the modern statistical methods that are useful in the control of variability in steel technology.

Large Power Reactor Authorized*

EARLY THIS YEAR the U.S. Atomic Energy Commission submitted to the National Security Council a statement of policy on the development of nuclear power.† The goal is a most difficult one, yet is essential to American leadership in the world. It is therefore proper to state some of the background.

Our atomic weapons program depends upon substantial quantities of uranium from friendly foreign nations which, I think, are motivated mainly by two beliefs: They believe in the military protection afforded by our atomic weapon potential. But they are also banking on the United States to help them build their nuclear power plants of the future. Unless we embark on a nuclear power program immediately, we may be deprived of foreign uranium ores with the result that our weapons potential will be smaller than need be the case. And so the two races — the atomic arms race and the nuclear industrial power race — are strangely related, and it should be quite clear that the stakes are very high.

Until recently, defense demands have limited large-scale nuclear power efforts primarily to military propulsion projects, such as submarine reactors. But the world situation, as well as the evolving progress of reactor technology, now calls for a great change of pace. With this in mind the Commission has embarked on a program to construct a power reactor to produce a minimum of 60,000 kw. of electrical energy. We hope to have it in operation in three to four years.

Because of Westinghouse Electric Corp.'s previous experience with the reactor system chosen,‡ this company has been named principal contractor. Immediate responsibility for the job has been assigned to Rear Admiral H. G. Rickover, the Navy's reactor expert. The commission will welcome offers from industry to invest risk capital in the building of the steam and turbine portions, as well the operation of the entire plant.

The new nuclear power unit cannot compete in costs with conventional steam power plants. Nevertheless, we decided to construct a unit designed according to the technology known now or within reasonable reach of the engineer's grasp. We have much to learn that can only be learned by building and by operating, and we will really never know the answer to costs until we build and operate several large-scale reactors.

The new installation will not be a "dual-purpose" reactor, to produce *both* power and plutonium. [Former proposals] expected that the premium price for the plutonium would bear any excess cost of the power. But today we are organized to take care of present weapons' demand for plutonium from reactors either now in operation or nearing completion.

This first full-scale reactor will not, by any means, be the sole effort of the Commission in the nuclear power field. We will continue our general programs of research and development, and promote the construction of experimental reactors which appear to contribute substantially to the design of economic units.

And now let us consider a controversial subject — the political aspect of industrial participation:

The Commission's proposed policy, calling for both Government and private efforts in the nuclear power field, is an interim policy. As privately financed efforts gain momentum, the work should gradually be transferred from the Federal Government so that eventually industry will be carrying the greater part of the burden of this industrial development. Initially the Federal Government must sponsor and finance full-scale power reactor development, but this will fall far short of what is needed unless there are enlisted the cost-cutting drives, the informations, skill and competition of many segments of America's business and industry. The time has come to end the monopoly of power reactor information now shared between the Government and a few industrial concerns [which have been "cleared" for studies about power reactors].

I don't think it is generally understood that the basic problem to the question of industrial participation is the need for secrecy. Were it not for a proper concern that the U.S.S.R. would capitalize for war on our reactor ideas and technology, all reactor data could be immediately published — for all in the free world to work on. Secrecy is a necessary nuisance. It does slow down the work of the Commission. It costs immense sums. But let's not compound its restrictiveness by making it the basis of what would really be a political preference for public ownership. And so another point of the Commission's power policy states: "Progress toward economic nuclear power can be further advanced through participation in development programs by qualified and interested groups outside the Commission."

In conclusion, I see the United States nuclear power policy is calling now, in the year 1953, for early development of practical power reactors. This means attacking the problem on a broad front, extending from our weapons material producing reactors at one extreme, through military propulsion reactors, through government financed full-scale power producing units, all the way to privately financed research, development and ultimately private construction of full-scale units.

*Verbatim excerpts from remarks by Commissioner Thomas E. Murray, U.S. Atomic Energy Commission, before Electric Companies' Public Information Program, Chicago, Oct. 22, 1953.

†See *Metal Progress*, September 1953, p. 73.

‡EDITOR'S GUESS—The submarine power plant (ship thermal reactor) successfully operated as a land-based prototype at Arco, Idaho. No detailed information about its construction has been released for publication.

Corrosion — How Best to Study It

The September issue of *Metal Progress* carried a "Critical Point" entitled "Corrosion — Do We Know Anything Much About It?" in which the view was expressed that a wholly disproportionate amount of work is being done along the Edisonian cut-and-try plan and that much more effort should be expended on what might be called the fundamentals of the problem. He cited two "centers" of research whereas he should have said two centers of fundamental research—for everyone knows that much work on specific problems is being done in many well-staffed and equipped university, governmental, association and industrial laboratories. Among the letters received since that publication the two printed below well state the case both for and against the Editor's view.

For More Fundamental Research

By John Chipman
Professor in Charge, Department of Metallurgy
Massachusetts Institute of Technology

The Critical Point entitled "Corrosion — Do We Know Anything Much About It?" in the September 1953 *Metal Progress* (p. 83) sets forth a very important and fundamental question. Research workers in the corrosion field would be practically unanimous in concurring with the answer that progress depends upon learning a lot more about it than we know at the present time.

And how do we start in to learn something about it? It is true that it won't be easy. The fundamental answers that are needed are not likely to be stumbled upon by following the "crisscrossed and well-worn paths of conventional test methods"—in the Editor's words. The underlying problems are those of physical chemistry and of physical metallurgy, and it should be clearly understood that where metals are concerned there is no line of demarcation between these two disciplines.

Stimulated by your Critical Point, I asked Prof. H. H. Uhlig of our department of metallurgy what he considered the important underlying problems in physical chemistry and physical metallurgy on which our further progress in understanding corrosion will depend. The following is quoted from Dr. Uhlig's reply:

"I believe that improved progress in controlling corrosion depends on (*Continued on page* 170)

A Defense of Ad Hoc Studies

By Frank L. LaQue
In Charge, Corrosion Research Section
International Nickel Co., Inc.

In Critical Points, September, 1953, the Editor raised a question as to how much we know about corrosion, deplored the dependence on *ad hoc* or empirical tests in selecting materials to solve particular problems, and made a plea for the creation of a sort of intellectual hot house from which lightning-like strokes of genius might flash to illuminate the surrounding darkness.

Since I spend most of my time dealing with the practical aspects of corrosion by trying to apply available data to particular problems, I am in a good position to recognize not only the deficiencies of the *ad hoc* approach and the need for more fundamental knowledge but also the difficulties of applying fundamental information to the solution of practical problems.

I am very much in favor of stimulating fundamental research by such methods as providing an environment and atmosphere that will attract gifted scientists to throw light on this involved subject. But I do not believe that we should seek support for such an enterprise on the basis that what we are seeking is a number of "lightning flashes", in the Editor's words. Lightning-like illumination is characterized as much by its brevity as by its brilliance. I would prefer the kind of thinking and systematic effort that might be (*Continued on page* 173)

Controlled Atmospheres— Their Generation and Utilization

THE NUMBER of possible combinations of controlled-atmosphere generators and furnaces available to the heat treating industry today is so large and varied that almost any desired metallurgical result can be produced. Choice of the proper combination is the joint responsibility of the supplier and the user, and should be made with due consideration to product quality, quantity, safety, economy and simplicity of operation. This implies closer cooperation between furnace manufacturer and heat treater than is normally necessary for other types of equipment.

The user of controlled atmospheres has a responsibility beyond the choice of equipment. The only purpose of a controlled atmosphere is the regulation of chemical reactions which will have an effect on the work he is treating. If he is to insure continued successful and economical operation during the lifetime of the equipment, he must have a good understanding of the process and exercise care in maintenance and control. It cannot be emphasized too strongly that vigilance pays dividends in the operation of controlled-atmosphere equipment.

Controlled atmospheres in their more elementary forms have been widely used for more than 20 years. Relatively complicated and highly specialized types of atmospheres are in use today, and generators which will produce them in the easiest and most economical manner have been designed. Although commercial heat treating companies as well as many production plants have no extensive chemical or metallurgical facilities, they are, nevertheless, called upon to use controlled atmospheres in many processes. It is under such conditions that correct equipment, protective maintenance and working knowledge of the gas-metal reactions involved are essential.

Practically speaking, gas-metal reactions encountered in present day heat treating processes can be classified as (*a*) oxidizing or (*b*) reducing, and (*c*) carburizing or (*d*) decarburizing. (For a tabulation of these reactions, see *Metal Progress* Data Sheet No. 63.) An oxidizing reaction will scale or discolor metal surfaces, whereas a reducing atmosphere will preserve clean metal and, in fact, can reduce oxides or scale to pure metal again. Carburizing or decarburizing reactions will affect those metals that either dissolve or give up carbon in the presence of a suitable gaseous atmosphere.

OXIDIZING-REDUCING REACTIONS

If, in the process of heating iron or steel – or any common metal – oxidation or scaling should be desirable, free oxygen or air would be an excellent atmosphere. If the metal were iron, one or more of the following oxidizing reactions would continue as long as any trace of free oxygen was present in the atmosphere:

$$2\,Fe + O_2 \rightarrow 2\,FeO$$
$$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$$
$$3\,Fe + 2\,O_2 \rightarrow Fe_3O_4$$

These reactions may be termed irreversible; in fact, they are uncontrollable since no product except oxide is formed.

There are other oxidizing gas-metal reactions which, while they can produce all or most of the products formed by oxygen, are more useful because they can be controlled as to rate and extent. Thus, in the reactions

$$Fe + H_2O \rightleftarrows FeO + H_2$$
$$Fe + CO_2 \rightleftarrows FeO + CO$$

water vapor and carbon dioxide are the oxidizing gases. Unlike the reactions involving free oxygen, the products of oxidation now include hydrogen (H_2) or carbon monoxide (CO), both of which are reducing gases. It becomes evident that ultimately the quantity of reducing gas can become great enough to slow down and finally stop the oxidizing reaction of the water vapor or carbon dioxide. Furthermore, these reactions can be controlled so as to be

By O. E. CULLEN, Chief Metallurgist
Surface Combustion Corp., Toledo, Ohio

Equilibrium Ratios for Gas Atmospheres

oxidizing, reducing, or neutral, depending upon the amounts of the oxidizing or reducing gases present. Such reactions are called reversible and represent the most elementary types of controlled atmosphere. Once the values for reversible reactions involving a particular metal are known, it becomes possible to produce a suitable controlled atmosphere for that metal.

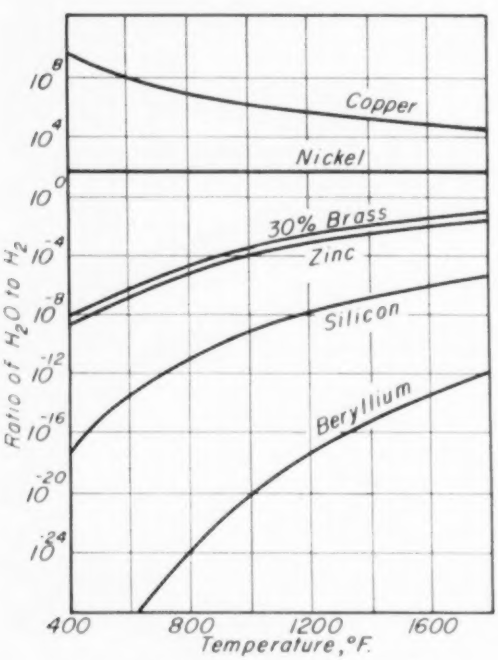


Fig. 1 – Ratios of Water Vapor to Hydrogen for Various Metal-Metal Oxide Equilibria as Functions of Temperature

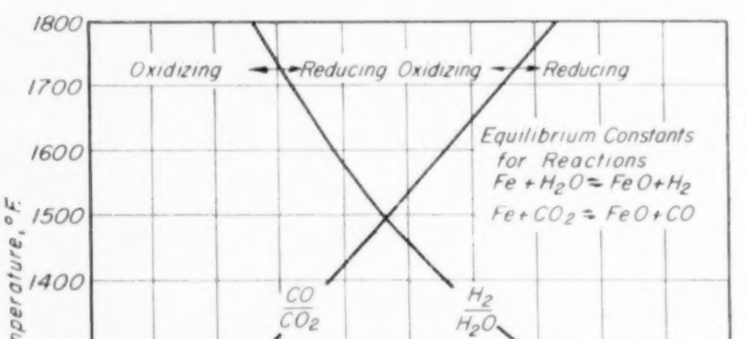


Fig. 2 – $CO:CO_2$ and $H_2:H_2O$ Equilibrium Constants for Oxidizing-Reducing Reaction With Iron or Steel. Note that the $H_2:H_2O$ ratio (horizontal) is vastly magnified over Fig. 1

In Fig. 1, equilibrium ratios of water vapor to hydrogen are shown over a range of temperatures for four common and two uncommon metals. Above each equilibrium curve the mixture of H_2O and H_2 becomes oxidizing, and below each curve it becomes reducing. The curve for copper illustrates why this metal may be clean annealed in an atmosphere of substantially pure steam. The curves also indicate why nickel (and iron) are relatively easy to anneal without oxidation, whereas brass, zinc (and, similarly, chromium and stainless steels) are difficult to keep bright or clean without dry, high-hydrogen atmospheres and special airtight furnace equipment.

It should be noted that, as a rule, lower ratios of water vapor to hydrogen are required at the lower temperatures. It is for this reason that an atmosphere with controlled moisture content usually is introduced directly into the low-temperature zones and cooling chambers of continuous furnaces during annealing processes.

When treating iron or steel, other active gases may be used to advantage. In Fig. 2 the carbon monoxide-carbon dioxide equilibrium ratios are included along with the hydrogen-water vapor ratios for a considerable range of temperatures. These curves show that while a reducing atmosphere will tolerate increasing amounts of water vapor (compared to hydrogen content) with increasing temperature, the direct opposite is true of the CO_2 in the $CO:CO_2$ ratios. The opposing actions of these ratios may be combined and controlled according to the well-known water-gas reaction

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

This introduces a well-known constant depending upon the temperature of the reaction, thus:

$$K\ (\text{Temperature}) = \frac{(CO_2)\cdot(H_2)}{(CO)\cdot(H_2O)}$$

CONTROLLED-ATMOSPHERE GENERATORS

The earliest controlled-atmosphere generators were based on the principles of partial combustion of hydrocarbon gas with

air to form a gaseous mixture containing carbon monoxide, carbon dioxide, hydrogen and water vapor in controlled quantities to obtain the desired reaction. This exothermic type of controlled-atmosphere generator is still one of the most widely used in the bright or clean annealing of copper, copper-rich alloys and low-carbon steels. In its simplest form the exothermic atmosphere generator shown diagrammatically in Fig. 3 consists essentially of a mixer for hydrocarbon gas and air, a mixture pump, a combustion chamber and a water cooler of direct or indirect type as may be required.

This exothermic or "DX type" of controlled atmosphere was the forerunner of a number of different types of atmospheres, each designed for particular heat treating applications and all derived from readily available supplies of hydrocarbon fuels such as natural gas or propane. Table I gives approximate analyses of these atmospheres. (See also *Metal Progress* Data Sheet No. 64.) With the exception of the DX and RX gases, these atmospheres are used mainly in manufacturing where large-volume generators are required. The NX, HNX and HX types of atmospheres are produced from hydrocarbon fuels reacted at high temperatures with air, steam or both, and then subjected to exacting supplementary treatments involving chemical absorption, catalytic conversion, and drying to remove undesirable constituents. Generators have been perfected to produce these controlled atmospheres in the limited quantities required, and it is expected that they will become increasingly useful in the general heat treating field in the future.

The endothermic (RX) type of atmosphere contains substantially none of the oxidizing gases – carbon dioxide and water vapor – but does contain appreciable amounts of the reducing gases, carbon monoxide and hydrogen. The gas-air mixture required to produce such an atmosphere is too rich in hydrocarbon to burn; hence a source of external heat and presence of a catalyst are required to bring about the desired reactions. As shown in Fig. 4, the endothermic generator consists

Exothermic and Endothermic Generators

of a gas-air mixer, a mixture pump and one or more externally heated retorts in which the gas-air reaction takes place in the presence of a nickel catalyst. All gaseous reactions are completed in the retorts and the reacted gas is generally cooled for transmission to point of use. Sometimes the generator is included in the heat treating furnace and no intermediate cooling zone is required.

Endothermic atmospheres are widely and almost exclusively used for carbon control in the heat treatment of steel. It cannot be emphasized too strongly that in such installations it is vitally important to understand not only the operation and correct adjustment of the atmosphere generator but also the reactions which go on in the heat treating furnace and the influence of both generator and furnace on these reactions.

CARBURIZING-DECARBURIZING REACTIONS

While it is recognized that many metals react chemically with carbon, the essential reactions involving carbon and iron or steel (with no reference to presence of alloying elements) are as follows:

$$3Fe + 2CO \rightleftarrows Fe_3C + CO_2$$
$$3Fe + CH_4 \rightleftarrows Fe_3C + 2H_2$$
$$3Fe + CO + H_2 \rightleftarrows Fe_3C + H_2O$$

Table I – Compositions of Hydrocarbon Gas Atmospheres*

Type of Gas	Gas Constituents, % by Volume					
	CO_2	CO	H_2	CH_4	H_2O	N_2
RX	0.0	20.7	38.7	0.8	0.0	39.8
DX (Lean)†	10.5	1.5	1.2	0.0	0.8	86.0
DX (Rich)†	5.0	10.5	12.5	0.5	0.8	70.7
NX	0.05	1.5	1.2	0.0	0.0	97.25
HNX	0.05	0.05	3.0-10.0	0.0	0.0	Balance
HX	0.05-2.0	0.05-1.0	50-99.8	0-0.4	0-3.5	Balance

*Based on use of natural gas for atmosphere production.
†40° F. dew point.

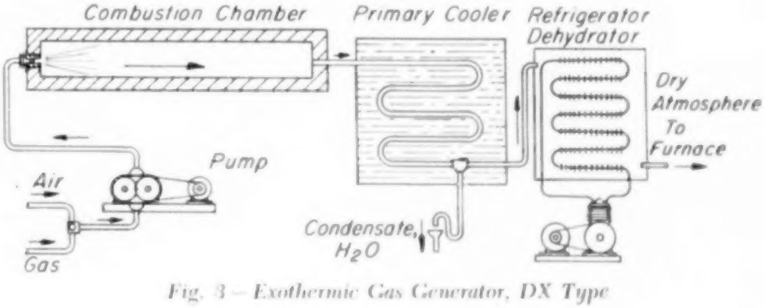


Fig. 3 – Exothermic Gas Generator, DX Type

Carburizing Reactions

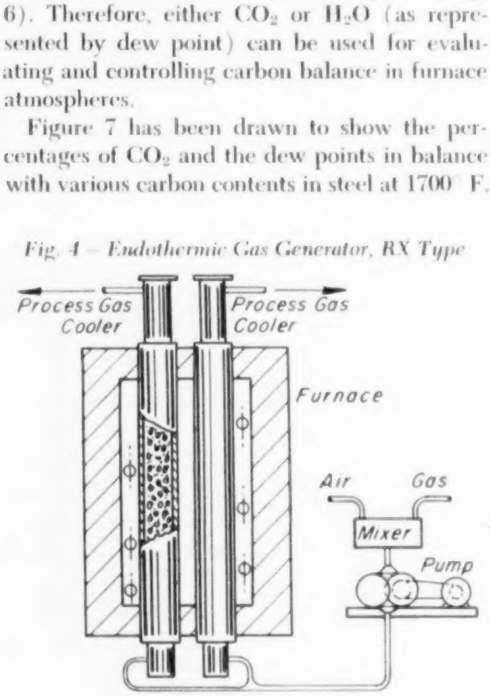
It is evident that carbon monoxide (CO) and methane (CH_4) are carburizing gases, and that carbon dioxide, water vapor and hydrogen are decarburizing. These carburizing reactions are reversible and the governing equilibrium ratios of $CO:CO_2$, $CH_4:H_2$ as well as $CO:H_2:H_2O$ have been described in *Transactions*, Vol. 38, 1947, p. 659. The endothermic type of atmosphere with approximately 20% CO, 40% H_2 and 40% N_2 has become almost universally recognized as a ready source for obtaining the desired carbon content in any heat treating process. The equilibrium values for $CO:CO_2$ ratios necessary for carbon concentration over the entire carburizing range have been worked out ("Dew Point Vs. % CO_2 as Furnace Atmosphere Control Check," by W. J. Groves, ***Industrial Heating***, June 1949). Figure 5 shows an example of such values at 1700° F.; it is evident that the CO_2 content for controlling carbon with the endothermic type of atmosphere is very small and the accuracy of reading these CO_2 values is beyond the usual limits of error. Groves has also shown that the water-gas reaction

$$CO + H_2O \rightleftarrows CO_2 + H_2$$

represents a definite relationship at any given temperature between the $H_2:H_2O$ ratio and $CO:CO_2$ ratio in the furnace atmosphere (Fig. 6). Therefore, either CO_2 or H_2O (as represented by dew point) can be used for evaluating and controlling carbon balance in furnace atmospheres.

Figure 7 has been drawn to show the percentages of CO_2 and the dew points in balance with various carbon contents in steel at 1700° F.

Fig. 4 – Endothermic Gas Generator, RX Type



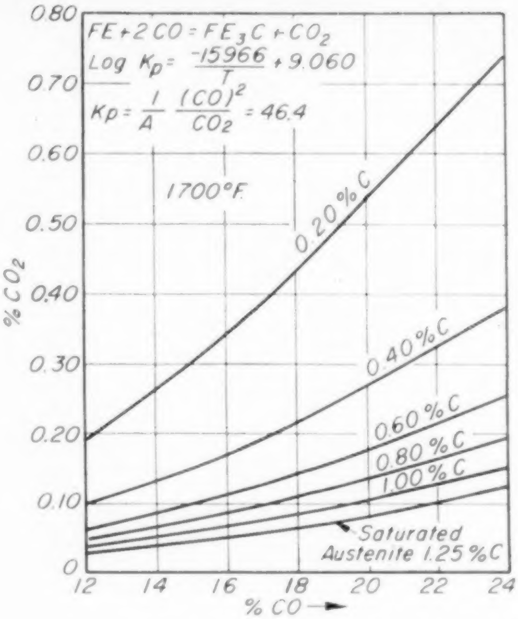
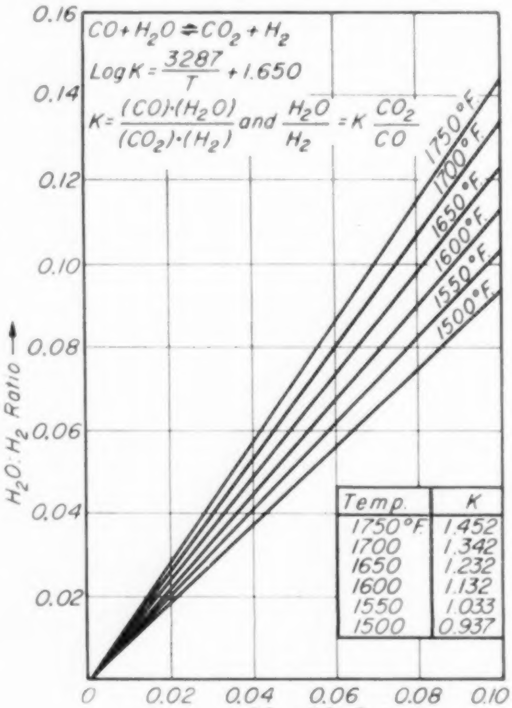


Fig. 5 – CO_2 and CO Percentages in Equilibrium With Various Carbon Concentrations at 1700° F. (Groves)

Fig. 6 – Relationship Between $H_2O:H_2$ and $CO_2:CO$ Ratios at Different Temperatures in Accordance With the Reaction $CO + H_2O \rightleftarrows CO_2 + H_2$. (Groves)



Temp.	K
1750°F.	1.452
1700	1.342
1650	1.232
1600	1.132
1550	1.033
1500	0.937

when heat treating in an endothermic atmosphere of 20% CO, 40% H_2 and 40% N_2. For equilibrium with a carbon content of 0.50%, an Orsat reading of 0.20% CO_2 and a dew point thermometer reading of 29° F. are required. For equilibrium with 0.60% carbon, the CO_2 reading must be 0.16% and the dew point reading 24° F. The difference in CO_2 readings for 0.10% carbon is 0.04% on the Orsat, whereas the difference in dew point thermometer readings is 5° F.

Figure 8 shows the limits of accuracy in controlling carbon by CO_2 and dew point readings, assuming that Orsat readings can be accurate within ±0.05 cc. and the thermometer readings within ±1° F. The chart shows, for example, that 0.60% carbon in steel can be controlled by Orsat readings of CO_2 only within limits of ±0.135% carbon or within a range of approximately 0.47 to 0.73%. By dew point determination the limits of control are ±0.023% or within a range of approximately 0.57 to 0.63%.

The usefulness of dew point control with endothermic-type atmospheres has been well proven in theory and practice. In Fig. 9 the curves represented by solid lines are drawn from theoretical data while each point on the chart represents an individual result obtained from actual furnace operation.

PRACTICAL CARBON CONTROL

It has been demonstrated above that an endothermic type of atmosphere, with proper adjustment of dew point or water vapor content, can be used to control the surface carbon of steel during heat treatment. In other words, a method is provided whereby steel of any particular carbon content can be hardened without substantial gain or loss of carbon at the surface. Also, steel which has been previously decarburized can be treated so as to restore the lost carbon; this may often be done during heating for hardening. A low-carbon steel can be carburized to any desired case depth with the assurance that a definite surface carbon concentration can be obtained. Examples of surface carbon control for carburizing over a relatively wide range of carbon potentials and case depths are shown in Fig. 10 on p. 106.

The foregoing discussion has been limited to the use of carbon monoxide as the carburizing gas merely to demonstrate the equilibrium conditions for maintaining desired carbon balance between a furnace atmosphere and steel surfaces. Actually, if there is any appreciable demand for transfer of carbon from the furnace atmosphere to the steel (as is true in most processes, including carburizing, carbon restoration and homogeneous carburizing), it becomes necessary to provide a sufficient extra supply. Carbon monoxide itself can yield only a little carbon to the steel, and only at the expense of upsetting equilibrium conditions. It is general practice, therefore, to supply the necessary carbon in the

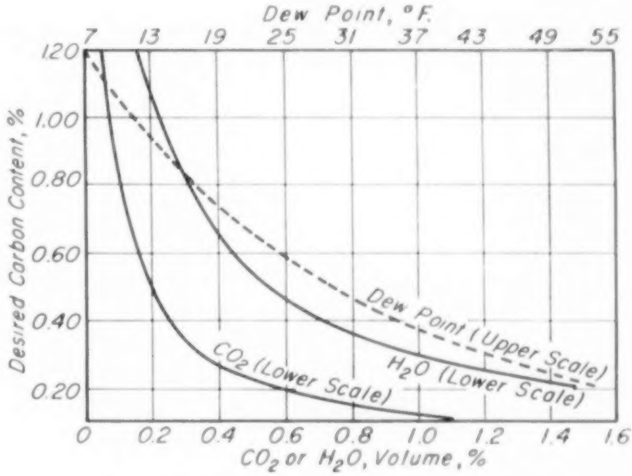


Fig. 7 – Carbon Control in Heat Treatment of Steel by CO_2 or H_2O Determination Using an Atmosphere of 20% CO, 40% H_2 and 40% N_2 at 1700° F.

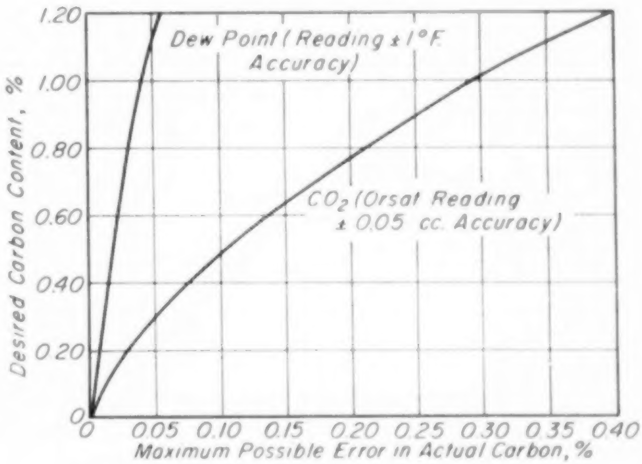


Fig. 8 – Limits of Accuracy in Controlling Carbon by Dew Point Vs. CO_2 Determination. Atmosphere is 20% CO, 40% H_2 and 40% N_2 at 1700° F.

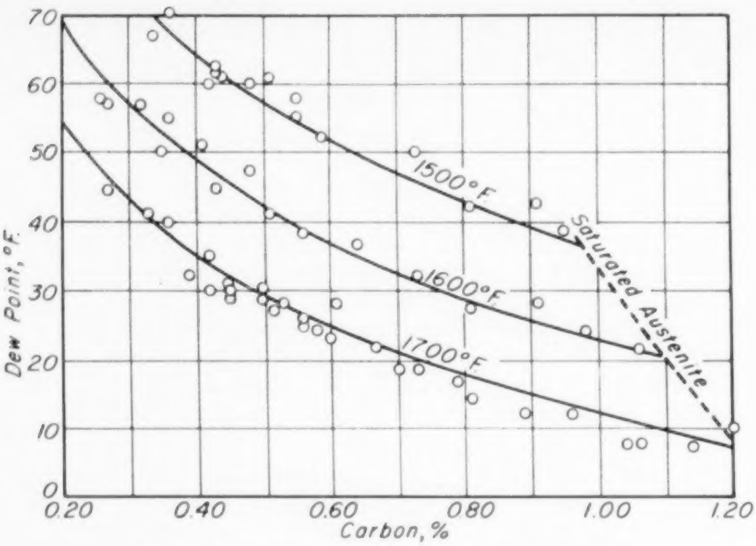
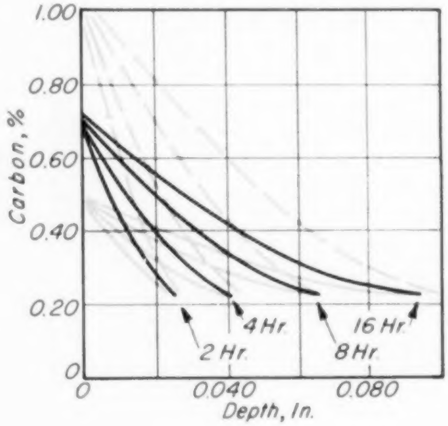


Fig. 9 – Dew Point as a Function of Austenite Carbon Content and Temperature for 20% CO, 40% H_2

form of a hydrocarbon gas added in carefully controlled quantities. For instance, a small amount of propane or natural gas (which usually contains a large percentage of methane) will provide the necessary enrichment. The available carbon in this methane or propane at carburizing temperatures is many times that of the CO in the generator gas. By controlling the amount of hydrocarbon gas on the basis of carbon demand by the steel, it is still possible to utilize the dew point method for controlling carbon balance between work and furnace atmosphere. This is true below the composition range for saturated austenite. Above this saturation range, time at temperature becomes the controlling factor – that is, surface carbon content of steel will increase with time.

Before the introduction of the endothermic type of atmosphere for gas carburizing, prepared gases containing relatively large amounts of carbon dioxide and water vapor were used, and it was necessary to add large amounts of hydrocarbon gases to overcome the bad effects of these constituents. The excess of hydrocarbon precluded the possibility of accurate surface carbon control and also led to soot deposition. This soot presented a cleaning problem and – far more important – the heat resisting alloy used in furnace parts deteriorated rapidly.

Fig. 10 – Carburizing Curves for Various Times and Carburizing Potentials. E.A.E. 1022 steel; RX Gas at 1685° F. Solid curves in color are for carbon potential of 0.50% C, black curves for 0.75% C, and dashed lines in color for 1.10% C



CARBO-NITRIDING

Further investigation of endothermic atmospheres brought out the possibilities of carbon control over all ranges. In gas cyaniding processes such as carbo-nitriding or dry cyaniding, endothermic gases become the element for carbon control as well as the diluent for ammonia gas which introduces the nitride constituent. Proper control of both dew point and ammonia content is necessary for such operations.

Processes involving carbon restoration at the surface and homogenous carburizing have been used in large production furnaces for some time, and hold promise for commercial heat treating plants and small industries as well. In these more specialized processes the prospective user must familiarize himself with the reactions involved and the best means for controlling them.

Uniformity of process control is obtained by a regular check on controlled atmospheres and furnace operating conditions. The frequency of such checks will depend upon the process. Competent foremen should be made responsible for continuous records of gas analysis, dew point and furnace condition. The equipment for making these records, such as Orsats, temperature indicators or recorders, portable dew-point instruments and automatic dew-point recorders, is readily available and comparatively easy to operate. If such testing equipment is used regularly, and the results interpreted properly, prompt adjustment can be made to the atmosphere generator, the heat treating furnace or the method of operation.

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

MANGANESE . . . Deoxidizer and Toughener for Steel

Manganese is one of the most important alloys used in making steel. It is practically indispensable as a deoxidizer and cleanser for improving the hot-working properties of steels. When used as an alloying element, it makes steel stronger and tougher and it is therefore an important constituent of many structural and engineering steels.

Deoxidizes and Cleans Steel

The effectiveness of manganese in deoxidizing steel was first recognized in 1856, when it was used in the Bessemer process of steelmaking to counteract the bad effects of sulphur; in fact, manganese made this process a commercial success. Today, manganese is used as a deoxidizer and cleanser in the production of nearly all grades of open-hearth and electric-furnace steel, as well as high-grade cast iron.

Research work carrried out recently in ELECTROMET's laboratories at Niagara Falls, New York, has provided new and important information on the value of manganese as a deoxidizer. This work shows that manganese is a more effective deoxidizer than has been previously realized; and that a combination alloy of silicon and manganese is a much stronger deoxidizer than either silicon or manganese by itself. Complete information is given in a report entitled "Solubility of Oxygen in Liquid Iron Containing Silicon and Manganese." If you would like a copy of this report, free of charge, write to the address above.

Improves Hot-Working Properties

By combining readily with sulphur, manganese performs another valuable job, it removes the principal cause of hot-shortness or brittleness—thereby giving steel better rolling and forging properties. In this reaction, the manganese combines with the sulphur to form manganese sulphide, as follows:

$$Mn + FeS = MnS + Fe$$

The manganese sulphide remaining in the steel is a less harmful type of inclusion than the iron sulphide would be, and the hot-working properties of the steel are improved.

The weakening and embrittling tendencies of sulphur in cast iron can also be counteracted by the addition of manganese to the cupola charge.

Increases Strength, Toughness, and Wear-Resistance

When used as an alloying element in steel, manganese produces a steel with greater strength and toughness, and there is no serious loss of ductility. Additions of about 13 per cent manganese produce the well-known Hadfield manganese steel. High-manganese steels have exceptional resistance to wear; and consequently they have many applications in engineering jobs. Instead of wearing away quickly under conditions combining severe pressure, shock, and abrasion, these steels actually become harder through use. Thus, they last longer.

Because of the tendency of high manganese steels to work-harden, they serve industry in important and varied applications. Manganese steel castings, for example, are used for railroad frogs and crossings, rock-crusher parts, steam-shovel dipper teeth, and dredge-bucket lips. The chief applications of manganese steel are in rails used for special service, and light forgings subjected to heavy wear.

Dipper bucket teeth, cast of Hadfield manganese steel, actually increase in hardness under abrasive wear from gravel and rock in construction work — thus last many times longer than those of ordinary steel.

ELECTROMET Alloys

Manganese is produced by ELECTROMET in forms suitable for practically every use of the iron, steel, and non-ferrous metal industry. Some of the ELECTROMET products are listed below. For a complete description of these alloys, write for a copy of the booklet, "ELECTROMET Products and Service."

Alloys of Manganese and Their Uses

Standard Ferromanganese	The product most commonly used for adding manganese to steel for the purpose of alloying or deoxidizing and cleansing.
Low-Carbon Ferromanganese	For adding manganese to steels having a low carbon content, such as stainless steels of the 18 per cent chromium, 8 per cent nickel type.
Medium-Carbon Ferromanganese	Commonly used for making manganese steel containing 1.50 to 2.00 per cent manganese, and in the production of Hadfield manganese steel.
Low-Iron Ferromanganese	For applications in the nickel, aluminum, and copper industries where a low-iron alloy is required.
Silicomanganese	Used by the steel industry as a furnace block; as a deoxidizer; and also for manganese additions, particularly in the production of engineering steels containing 0.10 to 0.50 per cent carbon.
"EM" Silicomanganese Briquets	For adding manganese (with silicon) to cast iron in the cupola.
"EM" Ferromanganese Briquets	For adding manganese (without silicon) to cast iron in the cupola.

Correspondence

Radiographic Studies of Segregates

PARIS, FRANCE

Dendritic segregation plays an important role in the directional properties of wrought steel by virtue of the fibrous structure in such products. The intensity of dendritic segregation (that is, the maximum variation of concentration) depends on the freezing conditions and the thermal history of the solid steel, and the elements under consideration. It appears as a ghost structure, the macrostructure being dendritic in non-wrought steels and fibrous in wrought steels. This macrostructure can be revealed by chemical reagents, but only to the extent of providing an over-all picture of the heterogeneity of concentration without revealing the effects of the individual elements. This has contributed to different opinions that attribute the etched structure to phosphorus, oxygen, and others. It is probable, as W. Grosse points out, that dissolved oxygen intensifies the segregation of phosphorus.

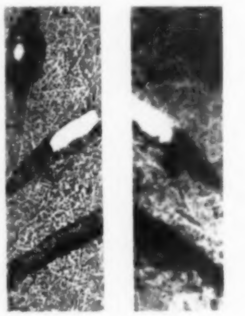


Fig. 3 – Steel Ingot Rejected for Ghost Lines. Macrograph obtained with Humphrey's reagent (left); radio-autograph (right)

Fig. 1 – Dendritic Segregation Shown by Radio-Autograph of a Steel With 0.76% C Containing 1.20% P. 10×

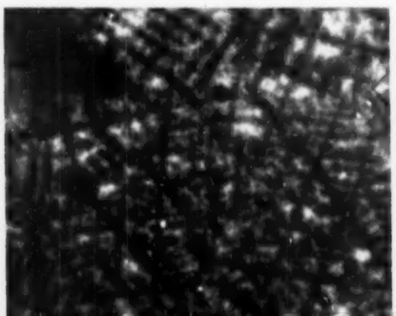
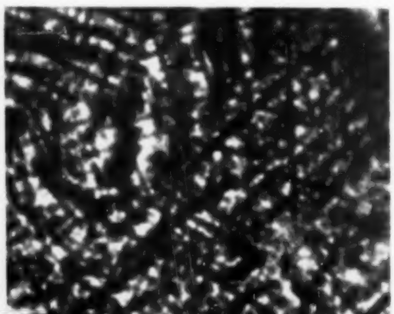


Fig. 2 – Structure of a Steel Containing 0.52% C and 0.34% P Irradiated Directly at the Chatillon Pile. 5×



Z. Weinstein and I have tried extending Bauman's method of sulphur printing by impregnating a gelatinized paper with an attacking reagent (for example, an acid) and a reagent that becomes colored when a specific metal is dissolved in its presence (such as dimethylglyoxime for nickel) as described in *Metal Progress*, March 1933, p. 52. We had no success with the method.

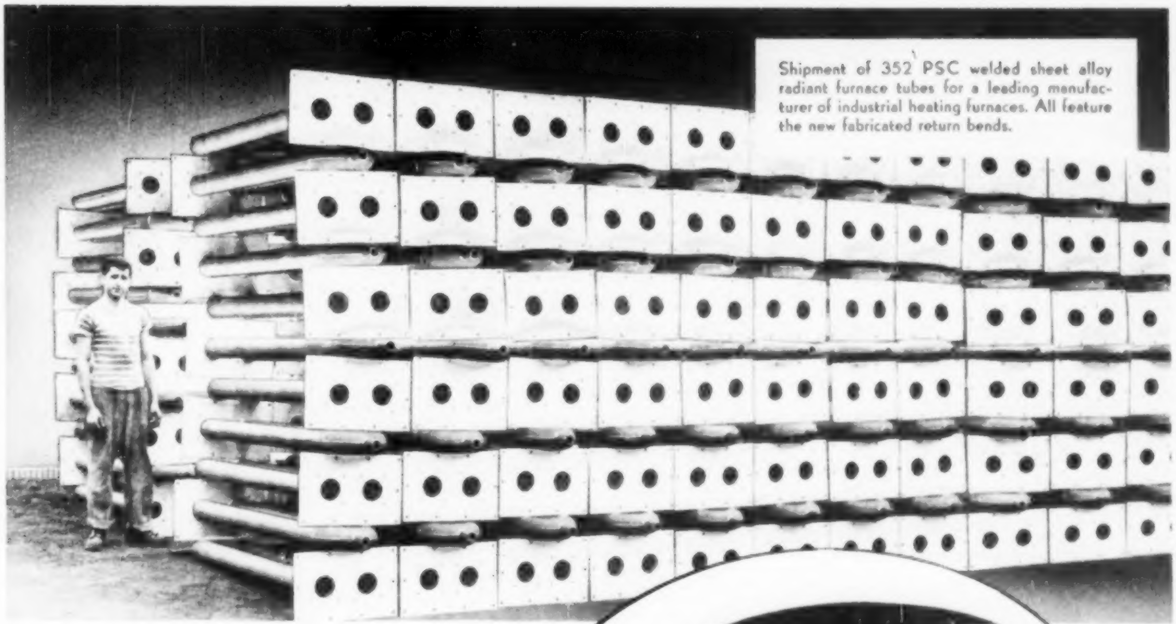
However, the idea was suggested that the use of radioactive elements offers a general solution to the problem, inasmuch as a direct photographic image of the distribution of the metal in question can be obtained. (See also "Radio-Autographic Determination of Lead in Stainless", *Metal Progress* for July 1951, p. 65.) Two possibilities arise with this method: The radioactive element could be introduced to the heat as ferro-alloy, or a plate exposed to neutron bombardment in an atomic pile could be used as the sample.

In the first method a single metal can be studied, but the method can be used only on small heats especially prepared for this purpose. The second is a more general method because it can be used on industrial ingots of carbon steel. André Kohn used this method at the laboratories of the Research Institute for Ferrous Metallurgy (IRSID) to reveal phosphorus and, to a certain extent, arsenic segregation, these being the only elements that give a photographic impression when the steel is exposed to a 48-hr. bombardment.

Traces of chromium in the steel reduce the definition in radio-autographs because chromium radiation causes considerable background fog. Traces of nickel or molybdenum are less troublesome.

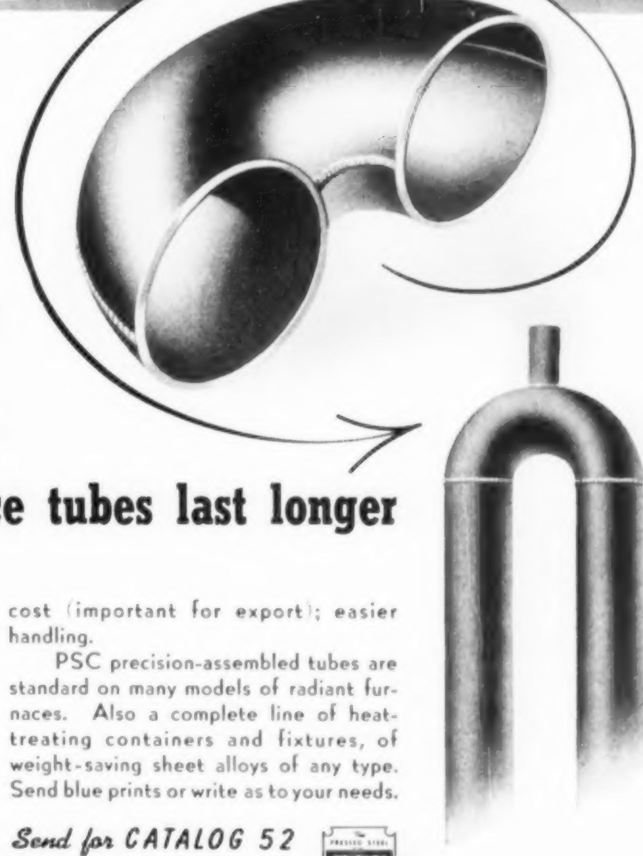
Figure 1 is a print at 10× from a radio-autograph of steel of 0.76% C and 1.20% P, the sample coming from a small heat made with additions of ferrophosphorus containing 15% radioactive phosphorus obtained by irradiation at the Chatillon pile. Figure 2 is a print at

(Cont. on p. 110)



Shipment of 352 PSC welded sheet alloy radiant furnace tubes for a leading manufacturer of industrial heating furnaces. All feature the new fabricated return bends.

PSC's *New* FABRICATED Return Bends



make radiant furnace tubes last longer

Here are three reasons why sheet alloy radiant furnace tubes equipped with the new PSC fabricated return bends are serving better: (1) Uniform wall thickness, and smoothness of interior result in uniform flow of gases; less cracking and burning out at the bends. (2) Light-wall construction saves heat-up time and fuel. (3) From 33 to 50% lighter than cast tubes: lower initial cost; lower freight cost (important for export); easier handling.

PSC precision-assembled tubes are standard on many models of radiant furnaces. Also a complete line of heat-treating containers and fixtures, of weight-saving sheet alloys of any type. Send blue prints or write as to your needs.

Send for CATALOG 52

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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Correspondence

5 dia. of a 0.52% C, 0.34% P steel irradiated directly at Chatillon. These clearly show the dendritic segregation of phosphorus. The first experiment with radioactive sulphur gave results similar to those in a normal sulphur print.

Figure 3 is a comparison of a macrograph obtained with Humphrey's reagent (left) and a radio-autograph (right) of an ingot of steel (0.56% C, 0.62% Mn, 0.44% Si, 0.39% Ni) which had been rejected for ghost lines. The autograph was made under conditions that rendered the arsenic more active than phosphorus. The veins are obviously rich in arsenic, a fact which is confirmed by the chemical analysis which disclosed 0.073% arsenic and 0.033% phosphorus in the lines as compared with 0.050% arsenic and 0.020% phosphorus near the lines.

This technique need not be confined to steels but offers a valuable new method of analyzing dendritic segregation in other metals also.

ALBERT M. PORTEVIN.

The Lighter Side of a Light Metal

PORTSMOUTH, VA.

Many strange designs have been observed in the microstructures of metals and alloys, but seldom do these designs take on any recognizable form. Recently, while making a routine microscopic examination of an aluminum alloy cast in our foundry, I chanced upon the accompanying design. Perhaps your readers will appreciate this "lighter side" of the metallography of aluminum alloys. It shows, at 500×, what I have called the "fourth phase" of this alloy. Actually, I believe it to be the Mg-Si phase separating out in the surprising numerical pattern below.

L. R. ABBOTT, JR.
Metallurgist
Norfolk Naval Shipyard

Detonation of Ti Alloy in Red Fuming Nitric Acid

DOWNEY, CALIF.

Our material research engineers suggest that you might be interested in a safety item concerning the handling of titanium-manganese alloys which have been corroded by red fuming nitric acid. The spongy residue of the alloys, which is formed after prolonged exposure to red fuming nitric acid, can be exploded by scratching the surface or by heating the material.

Extreme caution is urged in the handling of all titanium alloys which have been exposed to red fuming nitric acid, pending further investigation of safe handling methods.

JAMES F. SCHEER
North American Aviation, Inc.

Mechanical Properties of Carbo-Nitrided Cases

CAMBRIDGE, MASS.

The main objective of the article, "Structures and Properties of Some Carbo-Nitrided Cases" by K. B. Valentine in the June 1953 issue of *Metal Progress* appears to be an evaluation of the toughness of carbo-nitrided parts by bending and impact fatigue tests. Data of this kind have long been needed and Mr. Valentine has made a considerable contribution to the subject, but his experiments and interpretations call for comment.

A fundamental objection to this investigation concerns the conditions of carbo-nitriding, which are not representative of current practice. The treatments by which Mr. Valentine's specimens were made produce poor surfaces on the carbo-nitrided parts, which are certain to give poor results in bending and impact fatigue tests. Such surfaces are not formed in modern practice on parts that must have good fatigue and impact properties. The atmospheres and temperatures used in making Mr. Valentine's specimens would be satisfactory for parts that must only withstand simple wear.

Carbo-nitriding is practiced to a very limited extent in the range 1200 to 1400° F. Cycles similar to the author's treatments A and C are occasionally employed in industry. His treatment B comes closest to modern practice, but the ammonia concentration in the inlet gas should be given as 5% or less instead of 18%.

Correspondence

Also 1550° F. is a comparatively low temperature. The temperature range of carbo-nitriding for best mechanical properties extends as high as 1650° F. A decrease in ammonia and an increase in temperature would result in eliminating the outer layer present on the author's specimens and would improve their performance in bending and impact fatigue tests. The amount of retained austenite would also be reduced and this would raise the hardness values.

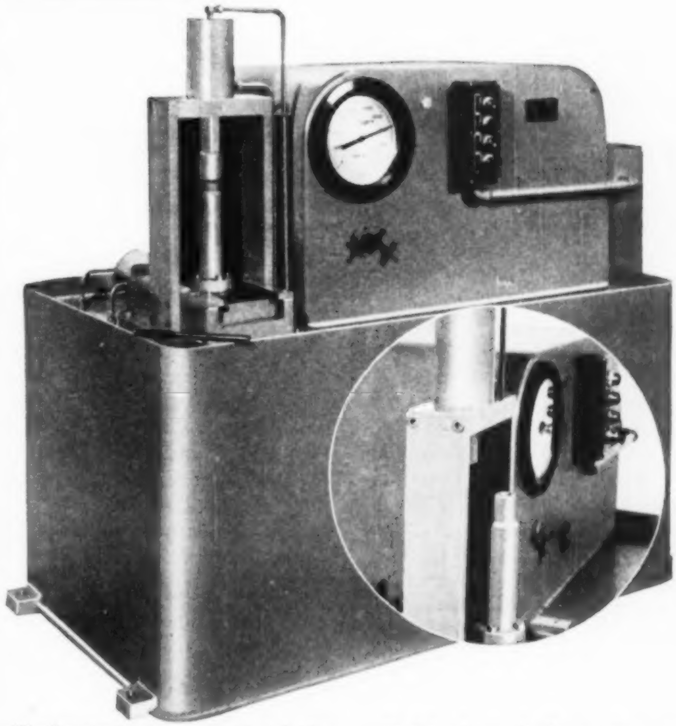
For given concentrations of nitrogen and carbon, carbo-nitrided cases are essentially the same as cyanided cases and should give similar results. The carbon and nitrogen concentrations can be controlled in carbo-nitriding by control of the temperature and the ammonia content of the furnace atmosphere.

Mr. Valentine's carbo-nitrided cases tend to have maximum hardness values not at the surface but at a depth of 0.004 to 0.006 in. The plain carbon steel carbo-nitrided by treatment B is actually harder at that depth than the maximum hardness of the cyanided cases.

The dark constituent at the surface of carbo-nitrided cases was mentioned by Bever, Floe and Zaruba in the May 1953 issue of *Industrial Heating*. It seems doubtful that this constituent is carbon precipitating out of solution because of the loss of nitrogen. Specifically, the statement by Rengstorff and his associates to which Mr. Valentine refers concerns the probable loss of nitrogen at rates of cooling slower than air cooling. At commonly used cooling rates, such as oil quenching, nitrogen loss would be negligible. The dark constituent is only found in the outer or compound layer. Since no such layer is formed in the most representative carbo-nitriding practice, the dark constituent is only of limited interest.

In conclusion, while Mr. Valentine's work is valuable in drawing attention to the important problem of the mechanical behavior of carbo-nitrided cases, it does not provide a sound basis for a comparison of carbo-nitrided and cyanided cases.

M. B. Bever and C. F. Floe
Department of Metallurgy
Massachusetts Institute of Technology



Personal Mention

R. E. Christin

R. E. Christin ("Ernie" to his many friends) has resigned as chief metallurgist for the Columbus Bolt & Forging Co., Columbus, Ohio, a position he has held for the past 29 years. Mr. Christin will devote his entire time to metallurgical consultation on steel specifications and steel processing in the Columbus area. He will continue to operate his own company, the Electric Heat Treating Co., which has been servicing Columbus firms by scale-free heat treatment in molten salt baths for the past two years. Prior to joining Columbus Bolt & Forging Co. in 1924, Christin was assistant metallurgist at Chrysler Corp.'s Highland Park plant and also an assistant melter on the electric furnaces at the Highland Park plant of the Ford Motor Co. He is a graduate of the University of Detroit, class of 1920, with a bachelor of science degree in mechanical engineering, and is an Ohio State registered professional engineer. He is a charter member of the Columbus Chapter and has served that group as secretary for 17 years. Mr. Christin is also a member of the American Welding Society, American Society of Safety Engineers and the Foremen's Club of his home city.

R. E. Sheffer is now manager of the Chicago Works of the Aluminum Co. of America.

Thomas Rutherford, district sales manager of the Midvale Co., Philadelphia, has been elected a director of the Alloy Casting Institute of Long Island, N.Y.

John J. McGrann has been promoted from sales engineer to district manager of the steel and tube division, in charge of the Houston, Tex., office of Timken Roller Bearing Co.

Walter J. Prochak has been appointed assistant superintendent of the cold drawn bar department at the Brier Hill works of the Youngstown (Ohio) Sheet and Tube Co.

John E. DeMoss, formerly assistant professor of metallurgy at the University of Notre Dame, having served twelve years as a faculty member, has accepted the position of chief metallurgist at Keystone Carbon Co., St. Mary's, Pa., and will be concerned primarily with developments in the field of powder metallurgy.

Moses A. Levenstein has completed two years' active duty with the Navy as laboratory officer at the USN Metals Laboratory, Munhall, Pa., and is now employed at the aircraft gas turbine division of General Electric Co. at Evendale, Ohio, as a welding engineer.

Daniel J. Gentile has joined the Lindberg Steel Treating Co. as a sales engineer for the Los Angeles division, after having been associated with Federal-Mogul Corp. for 25 years.

Frans Josef H. Rolink, formerly chief metallurgist for Doorne's Truck and Trailers, Eindhoven, Holland, has joined Lips' Propellor Works, Drunen, Holland, as assistant to the manager. Mr. Rolink was representative for the Netherlands at the first World Metallurgical Congress in Detroit in 1951.

Peter Arnold, after graduating from Arizona State College, is employed in the engineering department of the Conveyor Co., Los Angeles.

John C. Bronson has joined the staff of the Los Alamos Scientific Laboratory of the University of California. Mr. Bronson was formerly employed by the Colorado Fuel and Iron Corp., Pueblo, Colo.

Clayton H. Carleton, who was formerly director of research for Federal Machine & Welder Co., Warren, Ohio, is now a member of the staff of the Warren G. Harding Senior High School in the same city.

Erwin O. Deimel, formerly research associate in the metallurgy department at Columbia University, is now senior research metallurgist with Utica Drop Forge and Tool Corp., Utica, N.Y.

Lee P. Johns has accepted a position as patent lawyer with Frease & Bishop, Canton, Ohio, after four years with the patent division of Argonne National Laboratory.

Ralph I. Swanson, formerly supervisor of research at the Gary Steel Works, division of U. S. Steel Corp., has been promoted to assistant to general superintendent of the Canton (Ohio) Roll & Machine Works of the corporation.

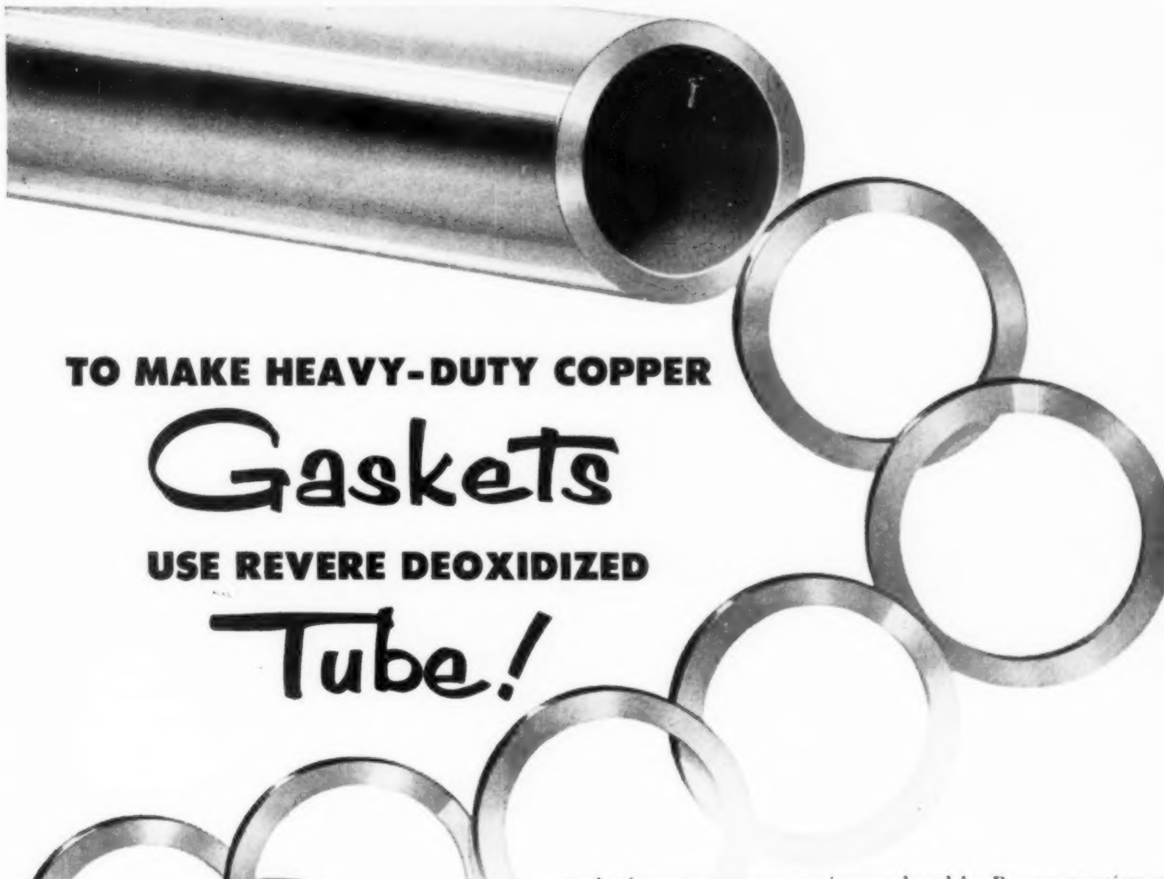
Charles Yaker has resigned from the scientific laboratory of the Ford Motor Co., where he held the position of supervisor of the foundry section, to join the Misco Precision Casting Co. as production manager of the Detroit plant.

L. G. Loseke, upon graduation from the Colorado School of Mines, was employed as a metallurgist by the Caterpillar Tractor Co., Peoria, Ill., and is now in the graduate training program of this company.

William A. Beck has accepted a position as assistant supervisor of the melting department of the Bay City (Mich.) Foundry of the Dow Chemical Co.

John J. Pierce has joined the staff of the National Bureau of Standards, Corona, Calif., as physical science administrator.

Dale Thomas Williams has been employed by Phillips Petroleum Co., Louisville, Ky., since graduating from the University of Kentucky.



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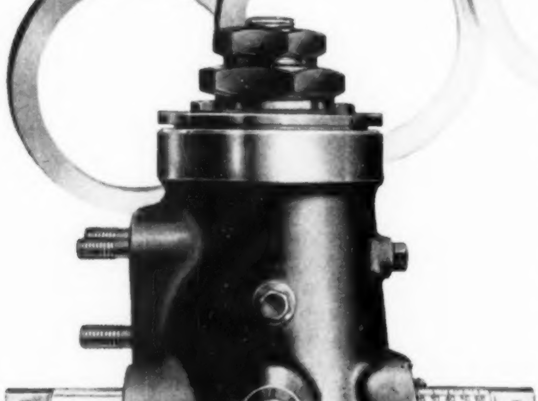

Diesel Fuel Injection Pump, made by American Bosch Corp., Springfield, Mass., and gaskets made by cutting rings off 2" deoxidized copper tube.

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Personals

Sidney M. Lenhoff, formerly employed with the U. S. Naval Bureau of Ordnance, Washington, D.C., as metallurgist, is now deputy (assistant) chief of Materials Branch, Detroit Tank Arsenal.

George R. Sublett, who graduated from Lehigh University in June, has accepted an assignment as metallurgical trainee at Reynolds Alloys Co., Sheffield, Ala.

C. M. Capka has been transferred from the St. Louis office of the Eclipse Fuel Engineering Co. to the Kansas City, Mo., office as manager.

Harold M. Cobb formerly unit head of the fabrication methods unit in the metallurgical engineering division of Wright Aeronautical Div., Curtiss-Wright Corp., Wood Ridge, N.J., is now metallurgist in charge of research and development, special products division of R. Wallace & Sons Mfg. Co., Wallingford, Conn.

Rollo W. Boring, formerly sales manager of Rolled Alloys, Inc., Detroit, was recently elected vice-president in charge of sales. **Robert C. Ford**, formerly associated with Carpenter Steel Co., Alloy Tube Division, has been appointed territorial manager of the same company and will be located in Pittsburgh.

Bernard E. Speranza, a metallurgical engineer with General Electric Co.'s chemical and metallurgical training program, has joined the Carboloy Department of General Electric Co. as an engineer in the carbide materials development section.

James M. Lommel, a June graduate of Illinois Institute of Technology, has been awarded first prize in the annual undergraduate essay contest sponsored by the Chicago section of the American Institute of Mining and Metallurgical Engineers. Mr. Lommel received his degree in metallurgical engineering and will do graduate work at Illinois Tech this fall under a fellowship awarded by the Allegheny-Ludlum Steel Corp., Brackenridge, Pa.

John W. Pennington has been named manager of the new technical department of the Metal Products Division of Koppers Co., Inc., Pittsburgh. Mr. Pennington joined Koppers in 1950 as chief engineer of the Division's piston ring department, and since 1952 has held the post of executive engineer for the entire Metal Products Division. His new responsibilities will include the supervision of all research and development activities for all product departments of the division as well as liaison with Koppers' central research organization.

Gordon H. Gillis, formerly superintendent of heat treating at Kropp Forge Ordnance Co., Melvindale, Mich., has joined the Carboloy Department of General Electric Co. as a heat treating engineer for coal mining tools in the carbide process and development section. Mr. Gillis is a metallurgical engineer from Missouri School of Mines.

Charles A. Cincilla, a June graduate of Lafayette College with a B.S. degree in metallurgical engineering, is now employed as metallurgist at the central foundry division of General Motors Corp. at Defiance, Ohio.

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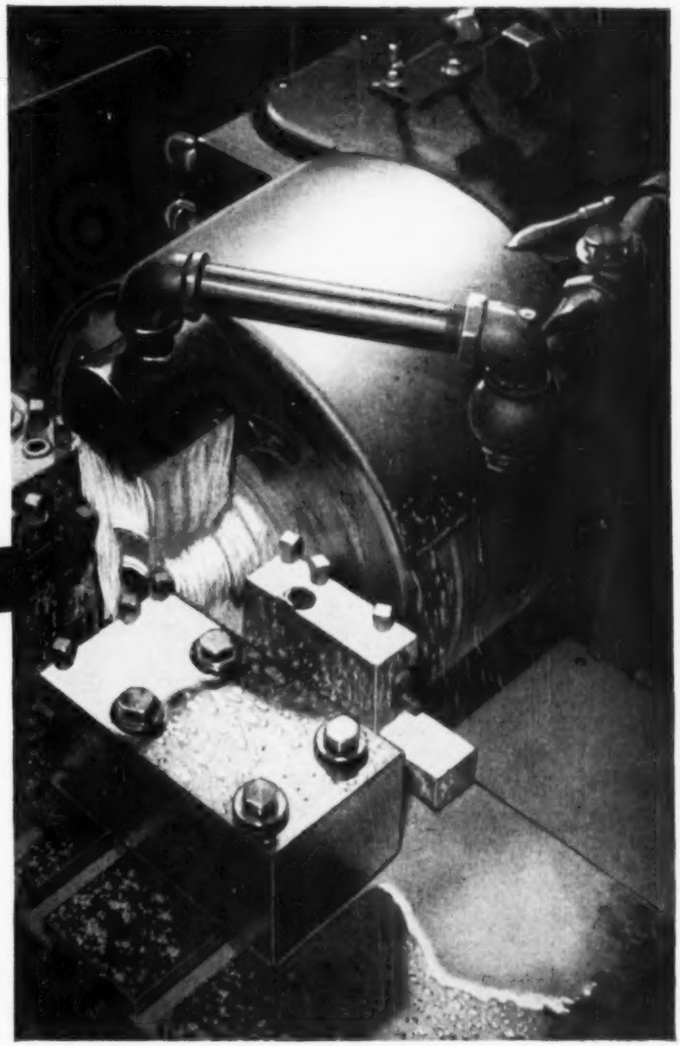

THE trial of Dasco in many plants has led to this judgment: Dasco Super Soluble Base is a heavy duty water-mix cutting fluid base of unusual versatility. It gives superior performance in mixtures of 1-40 and higher for turning, boring, reaming, drilling and milling and 1-100 and higher for grinding. Only unusual operations may require richer mixtures

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Dasco Performance: One part Dasco Super Soluble Base and 75 parts water on chucking machines increased tool life approximately 35%. Production increased from 50 to 400 pieces in 8 hours. Tool changes decreased from 27 tools per 8 hours using a competitive soluble oil to 12 tools per 8 hours with Dasco Super Soluble Base.

TRIAL 2 OPERATION: Drilling, counterboring and reaming 90MM Projectiles, A.I.S.I. 1055 forgings

Dasco Performance: Number of pieces per set of tools averaged 250 for a rich mixture of competitive heavy duty soluble oil. A 1-20 mixture of Dasco Super Soluble Base produced 500 pieces per set of tools.

TRIAL 3 OPERATION: Internal grinding of steel ring
Machine: Bryant Internal Grinder

Dasco Performance: A 1-150 mixture of Dasco Super Soluble Base replaced a 1-80 mixture of a competitive soluble oil. In addition the competitive product required a rust preventative. Dasco, even at the long dilution, has been in the machine over a month: no rusting has been experienced.

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Personals

Donald K. Tautz, having received a master's degree from the California Institute of Technology, has accepted a position with the California Research Corp., La Habra, Calif.

John O'Connor III has been named assistant sales manager of the Cleveland district office of the Copperweld Steel Co., Warren, Ohio, division.

Walter Grunden, Jr., formerly metallurgical laboratory supervisor of Perfect Circle Corp., New Castle, Ind., has assumed the duties of project metallurgist.

William A. Geisler has joined the staff of Lester B. Knight & Associates, Inc. Mr. Geisler has had 26 years' foundry operating, research and development experience in the United States and Germany, and is the author of a number of papers delivered in this country, England and Germany.

Willis Schalliol has joined the staff of Northern Indiana Brass Co., Elkhart, Ind., as manager of branches. Mr. Schalliol was formerly a supervisor of new fuel element development at General Electric Co.'s Hanford Atomic Products Operation, Richland, Wash.

D. C. Sanford has been appointed manager of the application engineering department of the Bristol Co., Waterbury, Conn. Mr. Sanford joined the company's sales engineering organization in 1937 and was promoted to Birmingham district manager in 1946. In 1948 he became an application engineer with headquarters at the company's main office in Waterbury, where he will remain.

Reinhardt Schuhmann, Jr. has been appointed professor of metallurgical engineering in the School of Chemical and Metallurgical Engineering of Pudue University, beginning with the second semester of the 1953-54 academic year, and will be chairman of the division of metallurgical engineering in the school. Dr. Schuhmann is now associate professor of metallurgy at Massachusetts Institute of Technology and has been at that institution since 1935. He holds degrees from the Missouri School of Mines, Montana School of Mines, and Massachusetts Institute of Technology. Professor Schuhmann is the author of the textbook "Metallurgical Engineering," and numerous technical articles.

C. W. Windfelder, formerly manager of the Carpenter Steel Co.'s Milwaukee mill branch warehouse, has been appointed assistant to the vice-president and will continue to be located in Milwaukee

W. J. Stephens has been promoted from sales engineer to manager of the St. Louis branch of the Carpenter Steel Co.

A. L. Thurman has been appointed executive vice-president of Mannesmann-Meer Engineering and Construction Co. after 7 years of mill machinery experience with Aetna-Standard Engineering Co. Prior to that time he was with the General Electric Co. for over 8 years, the last five years of that period having been spent as a steel mill application engineer in the G.E. steel mill division. Mr. Thurman's headquarters are in Easton, Pa.

Personals

John F. Richards, formerly employed as metallurgist for Simonds Saw & Steel Co., Lockport, N.Y., is now engaged as metallographer in the atomic energy division of Sylvania Electric Products Co., Bayside, L.I., N.Y.

Alfred E. Stone is in charge of the new sales and service division of Ipsen Industries, Inc., in Plainfield, N.J.

Newell Hamilton, formerly superintendent of the steel mill of the Babcock & Wilcox Co., Beaver Falls, Pa., has been appointed manager of steel operations in the tubular products division of the company. Mr. Hamilton has been with the Babcock & Wilcox Co. since graduating from Massachusetts Institute of Technology with his M.S. degree in physical metallurgy in 1928, and has been responsible for the development of several new alloys introduced by the division and their application to industrial uses.

Robert B. Clapper has joined Dow Chemical Co., Midland, Mich., as development and research engineer in the design section of the metallurgical laboratories.

Felix Kremp, after 2½ years on leave from Crucible Steel Co. of America to serve as chief of the tool-steel section, iron and steel division of the National Production Authority, has returned to company duties. Mr. Kremp is product manager for tool and specialty steel produced at the Park Works, with headquarters in Pittsburgh.

Norman W. Johnson, who was formerly with the major appliance division of General Electric Co., is now a principal metallurgical engineer at Battelle Memorial Institute, Columbus, Ohio.

Edward H. Platz, Jr., manager of alloy sales, Lebanon Steel Foundry, Lebanon, Pa., was appointed chairman of the public relations commitee of the Alloy Casting Institute. Assisting Mr. Platz on the committee is **C. M. Ruprecht** of the Electro-Alloys Division of American Brake Shoe Co., Elyria, Ohio. The commitee is active in promoting and furthering continued research in the production of both corrosion and heat resistant stainless steel alloys, and its function is to work closely with research and development at Ohio State University, Massachusetts Institute of Technology and Battelle Memorial Institute.

Hans W. Wawrousek has been awarded an Allegheny Ludlum Graduate Fellowship in the department of metallurgical engineering at Rensselaer Polytechnic Institute. Mr. Wawrousek received his bachelor of science degree from Rensselaer in 1951 and his master's degree in 1953, both in metallurgical engineering.

James H. Bly has been appointed research director of X-Ray Incorporated, Detroit, after a 13-year tenure with Pratt & Whitney, East Hartford, Conn.

Ross B. Hopkins has been appointed plant metallurgist for Rodney Metals, Inc., New Bedford, Mass. Mr. Hopkins, a graduate of Case Institute of Technology, has been associated with American Steel & Wire Co. for the past 13 years.

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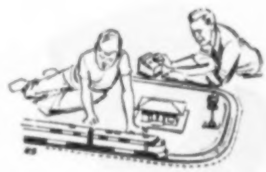

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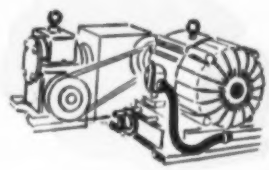

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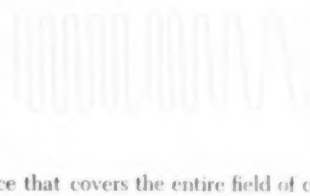

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Personals

Sam Tour has been elected president of the Metal Science Club of New York. Mr. Tour, a consulting metallurgist with 30 years' experience in the field, is manager of Sam Tour & Co., Inc., New York. **Howard S. Avery** of the American Brakeshoe Co. was elected vice-president of the Club, and **John P. Nielson**, professor of metallurgy at New York University, was elected to the post of secretary-treasurer.

Robert Maddin, associate professor at the John Hopkins University School of Engineering, is to spend 1954 as visiting lecturer in metallurgy in the department of metallurgy at the University of Birmingham, England.

Carl R. Anderson, formerly staff metallurgist, has been promoted to the position of assistant superintendent of the extrusion plant at the Lafayette Works of the Aluminum Co. of America in Lafayette, Ind.

Edward P. Rowady has completed the work in the chemical and metallurgical program of General Electric Co. and has been assigned to the laboratory unit of the company at the Allegheny Ludlum plant in Brackenridge, Pa., as a development metallurgist.

W. W. Sellers, formerly staff metallurgist at the Peoria, Ill., plant of the Caterpillar Tractor Co., is now quality control manager for the York, Pa., plant.

William W. Berkey, who was senior instructor in the metals technician branch of the department of crafts and trades training at Chanute Air Force Base, Ill., is now metallurgist in the research and development laboratory of the Reynolds Metals Co., Richmond, Va.

Howard W. Leavenworth, Jr. has been on the staff of the Franklin Institute, Philadelphia, as research metallurgist since graduating from Yale Graduate School of Engineering with an M.E. degree in metallurgy.

Robert C. Bates, a graduate of the University of Utah in June with a B.Sc. degree in metallurgy, is now metallurgist in the application section in materials engineering, Westinghouse Electric Corp., Pittsburgh.

Louis Horvath, a June graduate from Purdue University, is now with Bridgeport Brass Co. as assistant research metallurgist.

Roelof P. Steijn has resigned as assistant professor in mechanical engineering at Rice Institute, Houston, Texas, to accept a position as research metallurgist with the solid state physics group of the Franklin Institute, Philadelphia.

Lt. Raymond F. Decker, who has been stationed at Watertown (Mass.) Arsenal as metallurgical engineer in the foundry, has been ordered to overseas duty in Europe.

John A. Fellows, who has been associated with the American Brake Shoe Co. in metallurgical research since 1934, with time out during the war on assignment with the Manhattan Project, is now chief staff metallurgist for Mallinckrodt Chemical Works, St. Louis.

Robert J. Morris has resigned his position with the P. R. Mallory Co., Indianapolis, to enroll as a graduate student in metallurgy at the University of Cincinnati.

Harold P. Weinberg is now a materials engineer in the Research and Evaluation Division of the U.S. Naval Gun Factory, Washington, D.C.

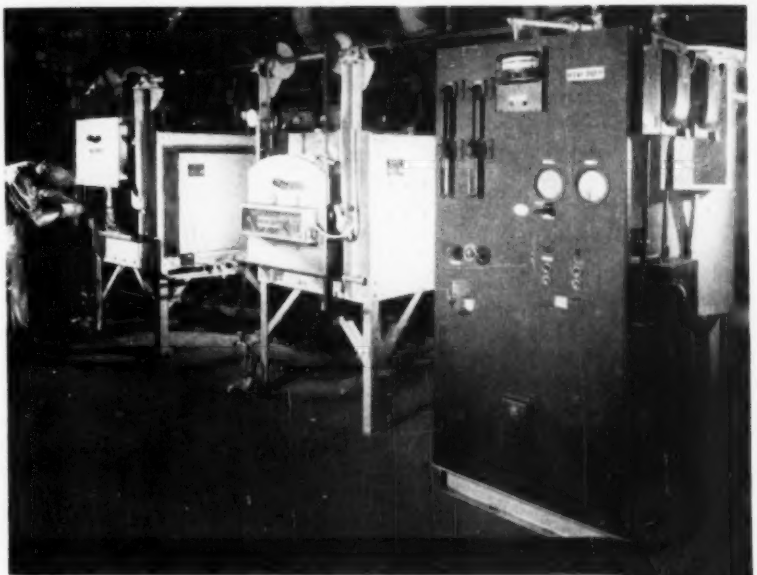
Michael A. Malachyn is employed as a sales engineer for the A. F. Holden Co., Detroit, covering the state of New Jersey, with headquarters in New Haven, Conn.

Russell A. Bain, formerly with the Harvey Machine Co., Torrance, Calif., is now a research engineer at the Los Angeles plant of North American Aviation, Inc.

Nobuo Abe, formerly manager of technical research department of Sumitomo Metal Industries, Ltd., Osaka, Japan, has been made chief engineer of the same company and is temporarily stationed in New York.

C. R. Sibley has been granted the Chicago Bridge and Iron Co. Fellowship at Rensselaer Polytechnic Institute, Troy, N.Y., and is now enrolled in the graduate school of metallurgy.

Paul E. Fedeles is employed as metallurgist for Latrobe Steel Co., Latrobe, Pa.



Diffusion Coatings*

Most of the various processes available for the surface treatment of metals and alloys utilize the mechanism of diffusion. Even electroplated and metal-sprayed coatings are often given a diffusion heat treatment to improve properties. However, it is with processes that involve a solid-gas reaction, such as in nitriding, carburizing and decomposition of a gaseous metal halide, that the principles of diffusion coating are most evident.

The speed of diffusion coating may be limited by the available supply of coating material at the base-metal surface, which frequently happens when plating from the vapor phase, or by the rate of diffusion into the metal base. Such a rate is difficult to calculate from simple laws of diffusion, since more than one phase is often present and small impurities in the base metal may have a strong effect. Thus, in the chromizing of steel, the addition of titanium to the steel greatly accelerates this rate of diffusion, whereas the presence of carbon acts as a retardant because of the formation of chromium carbide at the coating-core interface.

Deposition of metals by decomposition of a volatilized halide is a convenient method for many metals that are not easily deposited by other means. The mechanism may be one of metal replacement, of thermal decomposition, or of catalytic reduction (as by hydrogen) at the surface of the base metal. Using thermodynamic data for the metal chlorides, or other halides, one can calculate which of these reactions may occur, or if a combination is possible. Many iodides, carbonyls, and hydrides can be made to deposit by thermal decomposition alone.

In reviewing case hardening means, attention is called particularly to carbo-nitriding and its advantages in producing shallow cases having high hardness and good wear resistance. Although the mechanism of the process is not thoroughly understood, a necessary feature appears to be the securing of a higher diffusion rate of nitrogen than of carbon in the austenite-ferrite matrix. In gaseous carbo-nitriding, maximum hardness occurs slightly below the surface.

Siliconizing steel by both Ihrig's method and from a hydrogen-silicon tetrachloride mixture leaves much to be desired, although rates of deposition are higher than for chromizing. A 5% hydrogen-nitrogen carrier gas gave a good coating on mild steel, but unsatisfactory coatings were obtained on medium, high-carbon, or alloy steels. (Successful gaseous siliconizing depends on some factors not well covered in this paper, and its eventual field of application may be wider than the authors have indicated.) A promising field for siliconizing is in the protection of molybdenum from high-temperature oxidation. Also, molybdenum can be protected by hot dipping in an aluminum-silicon alloy bath, and heating to convert the film to a ceramic form like mullite or sillimanite. The deposition of refractory coatings by diffusion coating from the vapor phase constitutes an important new field, since so many combinations of metals, nitrides, carbides, borides, silicides, oxides and alloys can be so formed.

Diffusion coatings are of future importance not only in protecting the surface of a base metal against corrosion, oxidation or wear, but also in effecting economy in the use of scarce or expensive metals. Chromized low-alloy steels are being used in domestic appliances, in the food-processing industries, and for engineering components to pro-

(Continued on p. 124)

*Digest of "Diffusion Coatings", by D. M. Dovey, I. Jenkins, and K. C. Randle, *Journal* of the Institute of Metals, Symposium on Properties of Metals, 1952, p. 213-236.

Diffusion Coatings

(*Continued from p. 122*)

tect against room-temperature corrosion or elevated-temperature oxidation. An alloy coating of chromium and aluminum is preferred for applications over 1470° F. A chromized steel can be electropolished as well as polished mechanically. Siliconized coatings may find applications in combining corrosion resistance with wear resistance, as for the oil, chemical, and paper industries. Much remains to be done in the laboratory to gain information on effect of phase changes and other factors on diffusivity and on properties of diffusion coatings which have already shown their usefulness.

Although little new work is reported in this paper, it is an excellent review and discussion of this important field of metallurgy.

Bruce W. Gonser

Compression-Creep Machines for Elevated Temperatures*

The comparison of creep in compression with that in tension and the study of the initiation of third-stage creep and fracture have prompted the need for equipment to carry out compression-creep tests at high temperature with a precision similar to that normally obtained in tensile creep tests. The advantage of the compression test is that far less material is required for specimens. This factor prompted the metallurgy division of the National Physical Laboratory to design a compression-creep machine which was further developed in the Fulmer Research Institute.

The equipment consists of loading frames which can be accommodated in the loading shackles of a standard tensile-creep machine. The heavy upper loading frame, supported by the upper loading shackle of a tension-creep machine, contains an axial loading guide for the upper and lower specimen adapters while the lower framework, attached to the

(*Continued on p. 126*)

*"Digest of Equipment for Compression-Creep Tests at High Temperatures", by A. E. Johnson and N. E. Frost, *Engineering*, Vol. 176, July 3, 1953, p. 28-29.

Induction Heaters for Brass and Copper Billets

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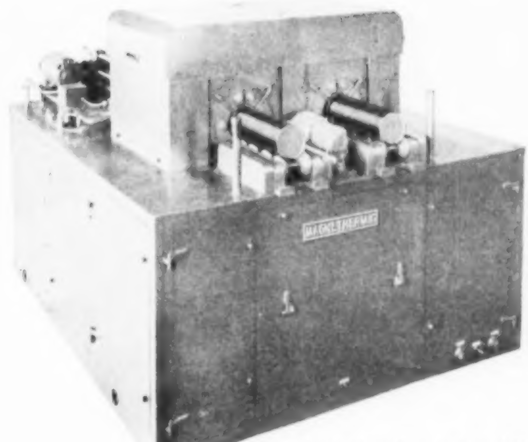
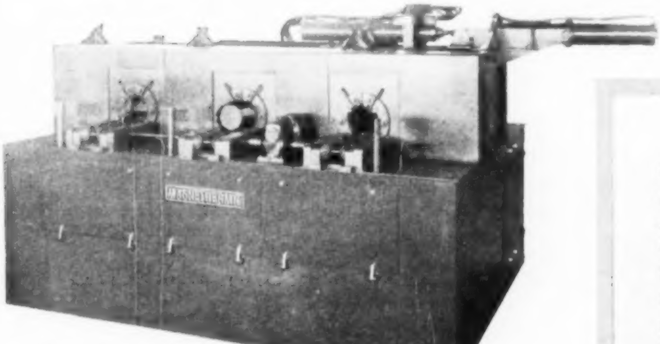
Magnethermic 60-cycle brass and copper billet heaters, now in operation, prove that they do reduce operating costs. Billets are heated in two or three minutes rather than hours. Temperature control is extremely accurate . . .each billet is discharged at exactly the same temperature. No warm-up time is required. On initial start ups, press the button, and in two or three minutes, heated billets are ready for further processing. No need to schedule billets ahead of time. Not more than three billets are in process at any one time.



2-coil Magnethermic brass billet heater rated at 7500 pounds per hour.



3-coil Magnethermic brass billet heater rated at 10,000 pounds per hour.

MAINTENANCE

Furnace damage is caused by heat. In a typical Magnethermic heater, the heating chamber is a tube 8" in diameter, 24" long, and water cooled for long life. In a conventional furnace, the heating chamber may be 40 ft. long, 8 ft. wide and 3 ft. high. It stands to reason that the latter will require many times the maintenance that the induction coil requires.
Then too, no need to shut down when relining the coil. Operate on the other coils, or put in a spare coil. Coils can be changed in ten minutes and relined in an hour or two.

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Magnethermic makes a single, two, or three-coil heater for any production requirement needed. All heaters are shipped completely assembled. Installation cost is at a minimum. Working conditions are ideal and floor space is negligible.
Heaters will operate equally well on extrusion billets, piercer billets, or wire bars. If you have a heating problem, let one of our engineers discuss it with you. A letter or phone call will receive prompt attention.

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INDUCTION HEATING

Compression-Creep Machines for Elevated Temperatures

(Continued from p. 124)
lower loading shackle, is simply a rectangular frame which sits on a hardened steel ball at the top of the upper specimen adapter. Since the specimen adapter is axially guided and the load is transmitted through the ball joint, axial loading is obtained with freedom from sideway thrust.

The furnace is located within the two frameworks and encloses the specimen, the specimen adapters, and a spherical seat. The spherical seat located at the upper end of the specimen is made of Stellite while the adapters are made of Nimonic 80 alloy.

The furnace capable of attaining temperatures up to 1290° F. is split longitudinally. The winding is tapped to facilitate adjustment of the specimen gradient to within 3.5° F. A platinum resistance thermostat maintains temperature to ± ½° C. (0.9° F.).

The standard specimen is 0.357 in. diameter and 1 in. long. Limitations are imposed on the diameter; it must be large enough to prevent buckling and small enough to minimize end effects. The ends of the specimen are flat (no special features have been incorporated but the frictional forces are minimized by applying a graphite coating).

The extensometer rods are attached to the specimen adapters at the specimen ends and extend downward out of the furnace. Rhombs carrying mirrors are placed between the rods on each side of the specimen and the strains are measured with a telescope. This is similar to that used in tension tests. Increments of strain of the order of 10^{-6} can be measured. Although the extensometer rods are not attached directly to the gage length, very little error is encountered since the stress in the end pieces is kept very low. This factor, however, limits the maximum working temperature to about 1290° F.

This equipment can also be used for short-time compression tests and for the determination of modulus in compression. M. J. Manjoine

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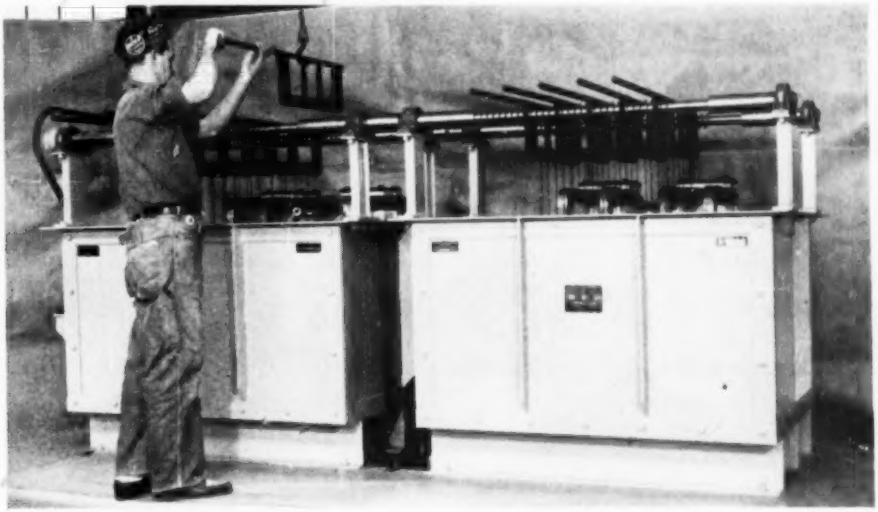

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Precise

Because temperatures of liquid salts can be controlled within two to three degrees, you can get the same close tolerances in your heat-treating as you demand from your machine shop. And you can get it batch after batch, week in and week out because Houghton Liquid Salt Baths are pure and double-refined for stability.

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Study of Carbo-Nitriding of Boron Steels*

Numerous publications governing the use of boron-treated steels have appeared during the period of boron substitution for critical alloys. The papers have dealt with carburized hardenabilities, plain hardenability studies, as well as the mechanical properties and service behavior of boron-treated steels. Although carburized boron steels have received attention in the literature, little has appeared on the carbo-nitriding of these steels until the appearance of this paper.

In their investigation the authors employed A.I.S.I. 1020, 80B20, 94B17 and a propietary steel "Superkore AA" containing boron. Subsequent to normalizing, these steels were case hardened using a carrier gas enriched with methane; for carbo-nitriding the carrier gas was enriched with methane and ammonia. All carburizing was done at 1700° F. for 3 hr. with an atmosphere containing 95% carrier gas plus 5% methane. The carbo-nitriding was done at 1500, 1600 and 1650° F. for 4 hr. with ammonia contents of 15% at 1500° F., 10% at 1600° F. and 5% at 1650° F., plus 5% methane, the balance being carrier gas.

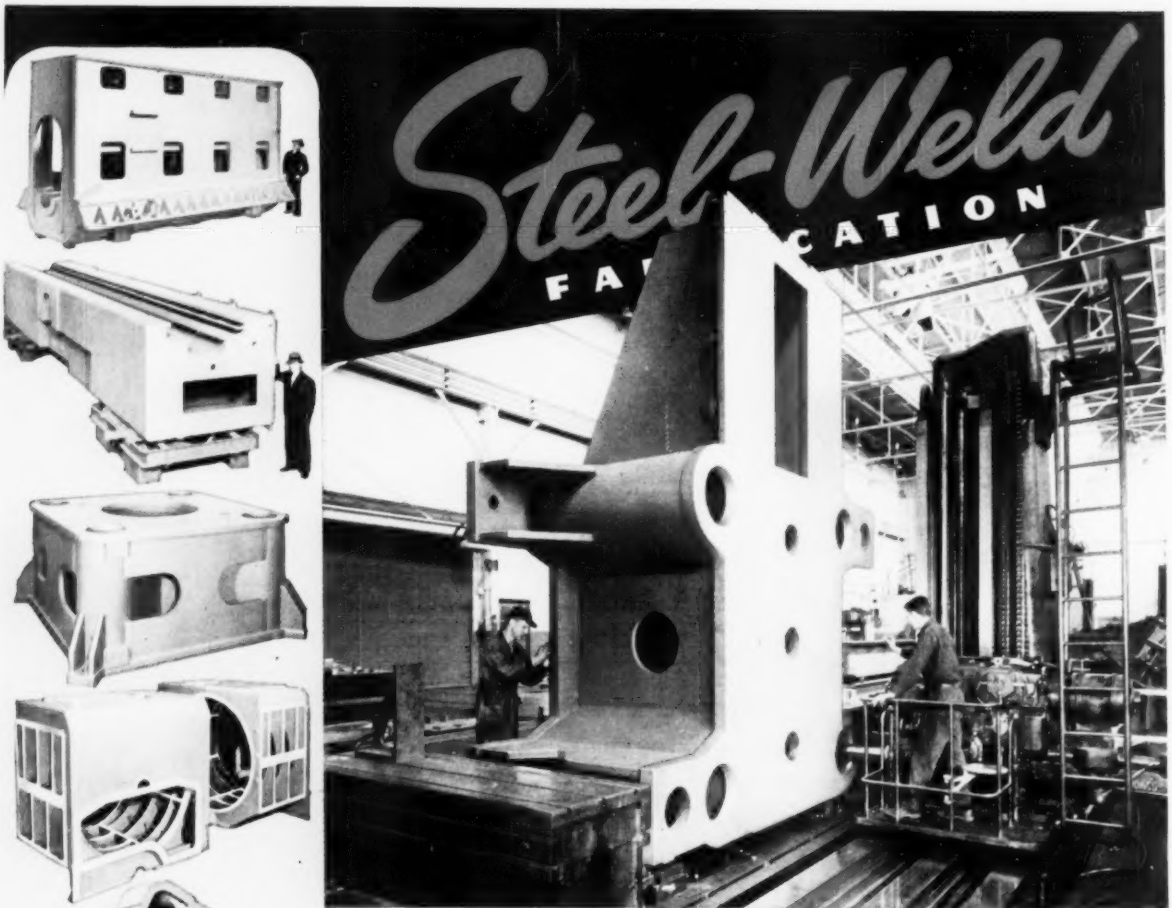
For the hardenability studies, carburized and carbo-nitrided bars were quenched by the standard procedure in the end-quench fixture. Results from these tests showed an increase in surface hardenability for the carbo-nitriding treatment. Jominy distance at Rockwell A-75 was 3/16 in. for the bar carburized at 1700° F., whereas the distances for carbo-nitrided bars were 11/16 in. for 1650° F., 12/16 in. for 1600° F. and 14/16 in. for 1500° F. Although smaller quanties of ammonia were used at the higher temperatures, a considerable increase in hardenability resulted. This increase in hardenability, the authors point out, is caused by the uncombined nitrogen in the case.

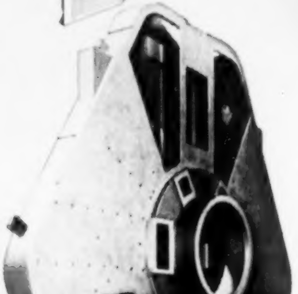
When these tests were repeated using boron steels, the carbo-nitrided bars were lower in hardenability than the carburized bars. Jominy distances at Rockwell A-75 for 94B17 were 10/16 in. for the 1700° F. carburized bar and 6/16 in. for the 1600° F. carbo-nitrided bar. The same hardness on 80B20 was obtained at 8/16 in. for the carburized and 5/16 in. for the carbo-nitrided bars. Again the authors refer to the nitrogen, contending that nitrides are precipitated in the boron steels which in turn nucleate the formation of pearlite and cause a reduction in hardenability. They contend that the low hardenability of the carbo-nitrided boron steels can be attributed to the interference of nitrogen with the action of boron.

Along with the hardenability samples, the authors ran ¾-in. square specimens for microhardness testing with the Knoop machine, these tests being through the cross-sectioned carbo-nitrided case. Results from these microhardness studies show that the maximum case hardness of 86B20 and "Superkore AA" is of the same magnitude as published data on conventional alloy steels, but that of the 94B17 is lower.

R. D. Chapman

*Digest of "The Carbo-Nitriding of Boron Steel", by G. W. Powell, M. B. Bever and C. F. Floe, 1953 Preprint No. 23.





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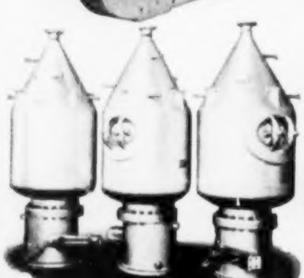

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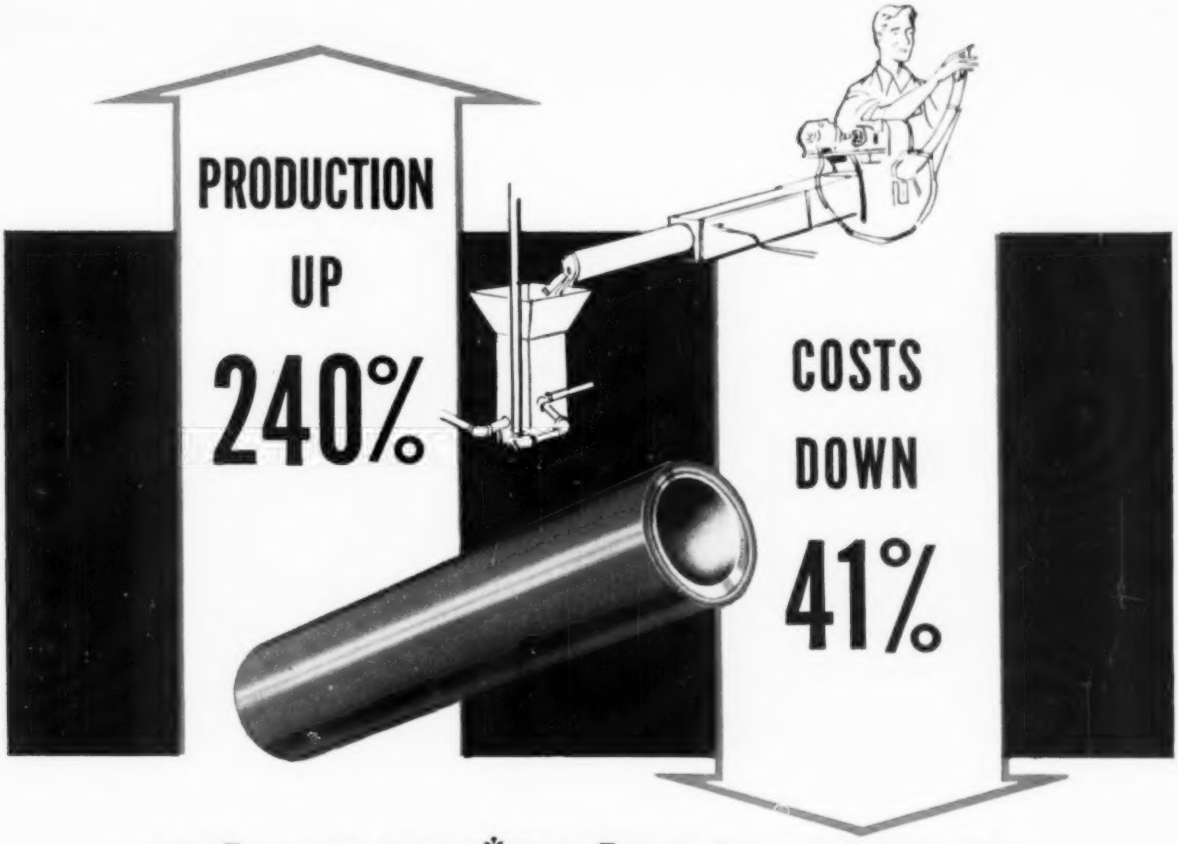

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Cracking of Soft Steel Under Stress and Corrosion *

This very comprehensive paper describes the stress-corrosion cracking of mild steel plates when immersed in solutions of calcium nitrate (860 g. per l.) and ammonium nitrate (30 g. per l.) at 100C°. (212°F.).

Ten different steels were studied: basic bessemer, rimmed and killed; basic openhearth, rimmed and killed with 0.08, 0.16, and 0.22% carbon; acid openhearth—in the form of hot rolled plate, 3/16 in. thick. Nitrogen contents varied from 0.003 to 0.013%. These combinations were selected after review of the literature on the stress-corrosion cracking of mild steels.

Various causes have been proposed: (*a*) absorption of hydrogen in the ferrite grain boundaries; (*b*) effect of stress concentrations at the bottom of cracks or pits; (*c*) locked-up stresses due to welding or other fabrication processes; (*d*) precipitation of some new phase such as iron nitride. Mr. Perkins' work indicates that none of these theories fully explain this phenomenon in mild steel.

The experimental procedure consisted of stressing 1-in. strips of the steels to different stress levels varying from 12,000 to 88,000 psi. in a special jig and then immersing them in the boiling nitrate solution. The time for cracking to develop was recorded for each stress level for each steel, and typical plots of the results are shown in the paper. Although none of the steels in the stressed, hot rolled condition cracked in the nitrate solution, most samples cracked if they had been previously cold strained (from 2% to 10%) prior to putting them into the test jig. The minimum stress then required to cause cracks varied widely for the different steels; the lowest stress was about 12,000 psi. for the bessemer rimmed steel and the highest was about 25,000 psi. for the acid openhearth steel. These stress values are based on a 50-hr. exposure. At

(*Continued on p. 132*)

★Digest of "Stress-Corrosion Cracking of Mild Steels in Nitrate Solution," by R. N. Perkins; *Journal* of the (British) Iron & Steel Institute, Vol. 172, 1952, p. 149-161.

Cracking of Soft Steel Under Stress and Corrosion

(Continued from p. 130)

higher stresses, each steel cracked more quickly.

These preliminary results indicated that method of manufacture (state of deoxidation) or chemical composition influenced the tendency for stress-corrosion cracking. Four of the steels, 0.18% carbon basic openhearth (rimmed), 0.18% carbon basic openhearth (killed), and 0.22% carbon basic openhearth (rimmed or killed) developed cracks in the cold worked, stressed condition only after long times (up to 2000 hr.).

The influence of low carbon content in decreasing the tendency of the stress-corrosion cracking was most significant. Since it had been observed by previous investigators that decreasing the carbon content below 0.003% and nitrogen below 0.0036% rendered the steel fairly safe, three of the steels (0.07% C rimmed bessemer, 0.18% C killed basic openhearth, 0.22% C basic openhearth) were annealed in wet hydrogen at 1325°F. for various times to obtain samples with different amounts of carbon and nitrogen. Many test pieces, after this annealing treatment, were cold strained 10% in the tensile machine, stressed, and immersed in the nitrate bath for various times. The low-carbon bessemer steel cracked in 10 to 40 hr. at carbon contents of 0.030 to 0.07%, but did not crack in 500 hr. when carbon was below 0.02%. The basic openhearth samples, which had carbon contents ranging from 0.03 to 0.16%, all cracked in 15 to 20 hr. The samples with more than 0.16% carbon and all samples with less than 0.02% carbon did not crack.

The author gives no details as to the relation between the nitrogen remaining after wet hydrogen annealing, and the cracking phenomenon. However, three steels were nitrided to 0.0035% and 0.096%. One steel was a 0.09% C bessemer grade with 0.007% initial nitrogen and two were basic openhearth steels with 0.18% and 0.22% carbon and initial nitrogen of 0.004%. Rapid cracking (less than 30 hr.) developed in all three steels when the

(Continued on p. 134)

Cracking of Soft Steel Under Stress and Corrosion

(Continued from p. 132)

nitrogen content was boosted to 0.050%, but no cracks in any of the steels were observed after 250 hr. immersion when their nitrogen exceeded 0.050%.

In a final experiment on the effect of nitriding on cracking susceptibility, samples of the 0.07% C bessemer steel were annealed in wet hydrogen to make them resistant to cracking and then nitrided to 0.095% N. (The carbon content was 0.015%.) Samples so treated showed no intergranular corrosion at any stress level after 300 hr. immersion in the hot test solution. Finally, a sample of high-purity iron (99.99%+) showed no cracking after 300 hr.

Microscopic observations indicated that the hot rolled samples with the higher carbons were very resistant to intergranular corrosion. The carbon was present in a normal pearlitic structure, intergranular corrosion oc- samples containing over 0.16% carbon were annealed at 1300°F. long enough to develop a spheroidized structure, intergranular corrosion occurred in very short times (1 to 100 hr.) depending upon the extent of spheroidization.

The results of other investigators, emphasizing that cracking occurs when a minimum stress is exceeded, and that previous cold plastic deformation is detrimental, have been confirmed. The tendencies to stress-corrosion cracking of these steels showed that the nitride precipitation theory is not generally applicable, and that the most important composition factor is associated with the carbon content and the structural distribution of the carbon; the cracking was found to be definitely related to the presence of cementite in ferrite grain boundaries. The author concludes as follows:

"A grain boundary is a region of inherent distortion, but the magnitude of the latter is increased when carbide particles are located in such regions and the material is cold worked. The ferrite in the region of the carbides will be distorted to a greater extent than elsewhere, owing to the presence of so-called

(Continued on p. 136)

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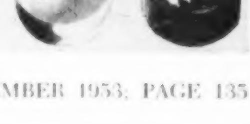

Cracking of Soft Steel Under Stress and Corrosion

(*Continued from p. 134*)

micro-stresses, and also to the concentration of plastic distortion in such regions when the metal is plastically deformed. The extent of the distortion is sufficient to make the material anodic to the rest of the grain, so that the localized corrosion takes place; this will be very severe, because of the small area of the crack in comparison with the cathode area. The small pit, formed by the corrosion, concentrates the applied stress in the region of its base, and this stress increases the potential difference between the base of the pit and the cathodic grain interiors. If distorted by previous cold work or the presence of a nearby carbide particle, the distortion accompanying the stress concentration moves the potential to a sufficiently anodic value for further corrosion to take place. The crack may thus be propagated over the resistant region to the next region of distortion."

E. C. WRIGHT

Metallurgical Light on Aircraft Heater Failures*

SELECTION of materials, design, coatings, welding procedures and metallurgical considerations all are factors in determining the service life of aircraft combustion-type heaters. They are being investigated, both in the laboratory and in flying aircraft, by plane builders, materials suppliers and the manufacturer of this type of heater.

One study, for instance, is being conducted to ascertain whether a change in material from the presently used 309 Cr-Ni stainless steel will prolong life of the heater. A further purpose is to determine to what extent a ceramic coating will be beneficial and whether there may be coatings other than ceramic which have possibilities. Materials such as Inconel, Haynes No. 25 and other

(*Continued on p. 138*)

*Abstract of "Metallurgical Aspects of Aircraft Heaters", *Aircraft Heating Digest*, Vol. 3, No. 1, August 1952, published by Surface Combustion Corp.

Metallurgical Light on Aircraft Heater Failures

(Continued from p. 136)
analyses of stainless steels are being evaluated to find out whether they have desirable properties which could be profitably exploited.

In another metallographic test on a heater returned from service it was discovered that the sigma phase (a hard, brittle, intermetallic compound of Fe and Cr) was present in the grain boundaries of all sampled areas in the heat-affected zone. Degree of the sigma phase in the grain boundaries indicated that the metal was exposed to temperature above 1200° F. In Type 309 stainless, sigma phase will form readily at temperatures of 1100 to 1600° F., the amount and rate of formation depending upon time and temperature, and the level of internal stress in the steel.

Cyclic operation of the heater, or a differential rate of heating of its various parts, promotes high stresses and these may be of sufficient magnitude to cause surface cracks in the grain boundaries where sigma phase is present. During the time at operating temperature, severe oxidation will occur in grain-boundary cracks because of depletion of chromium from the area when the sigma phase was forming. Repeated heating and cooling cycles finally cause the crack to penetrate the metal shell.

In the test just referred to, no cracking had occurred in a weld and the failure was due to oxidation or burn-through. Samples of a bright orange contaminating material were scraped from the inner surface in two areas and X-ray diffraction analyses made. In one area, at the combustion zone, the chief compounds present were $PbSO_4 \cdot PbO$, $PbSO_4 \cdot 2PbO$ and Pb_2O. Slightly downstream from this area a darker material proved to be a mixture of Fe_3O_4, NiO, $Cr_2O_3 \cdot NiO$ and FeNi. No bromine compounds were found in the latter area, suggesting that no reaction was taking place between the heat exchanger and bromine (from the gasoline) and that the temperature of the gases at this locality was high enough to prevent condensation of bromine compounds.

Presence of heavy lead sulphate and lead oxide deposits in the com

(Continued on p. 140)

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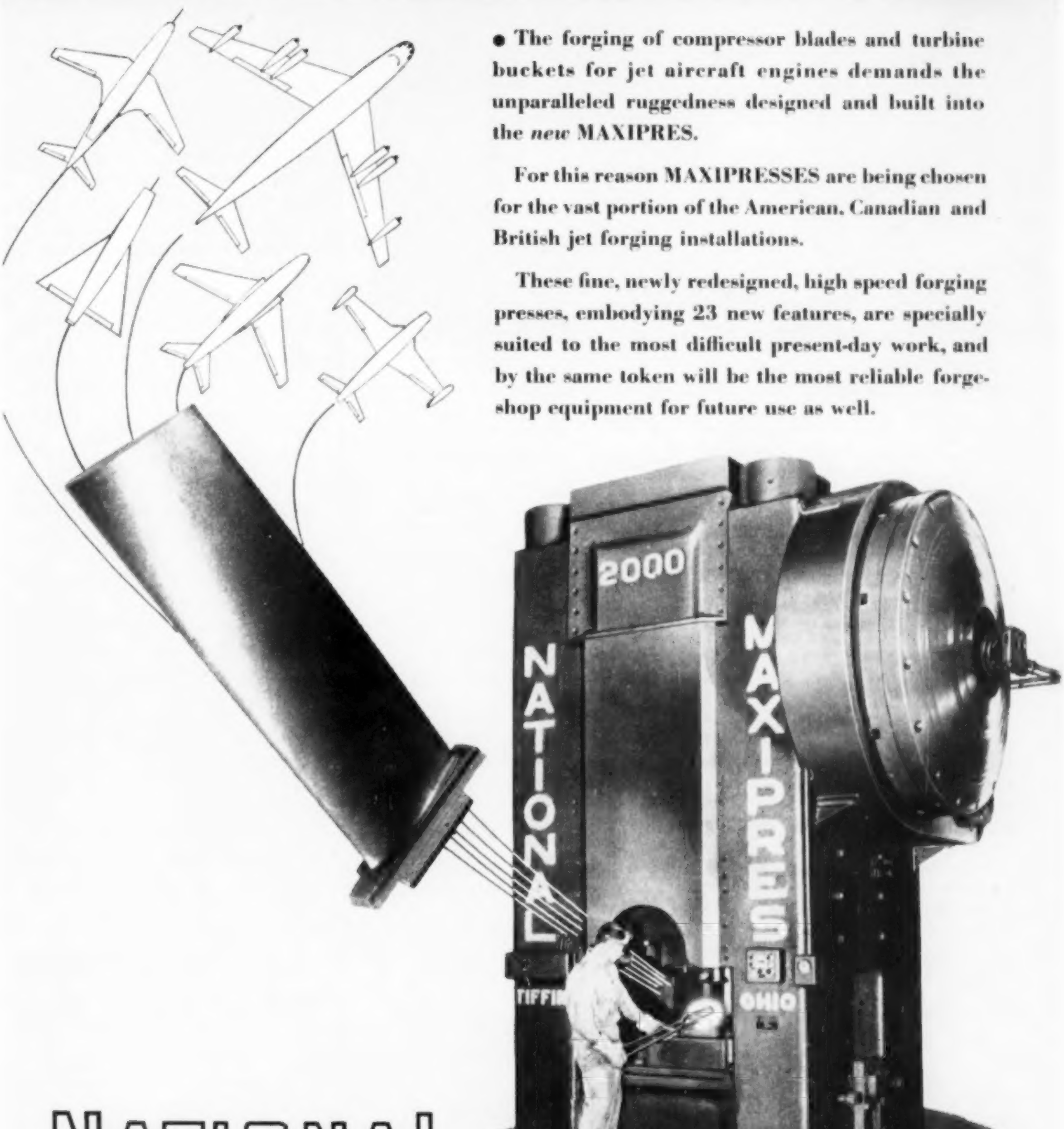

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Metallurgical Light on Aircraft Heater Failures

(Continued from p. 138)

bustion zone and crossover ducts indicate a rapid and severe oxidation action had caused failure. Molten PbO in contact with stainless steel will continually flux off the protecting chromium oxide on the surface of the steel. While the melting point of pure PbO is 1630° F., this is reduced considerably when the oxide fuses with other metallic oxides. A high percentage of oxygen in flue products, plus lead oxide, makes for a severe corrosive condition on stainless steel.

Further research on a variety of specimens, including 19-9 stainless, Type 309 and 310, Inconel and Haynes No. 25 alloy, some coated with a Type A 418 enamel and others coated with pure aluminum, gave some conflicting results. They suggest the danger of regarding laboratory tests as conclusive and the necessity for depending finally on behavior of the material under exact field conditions.

It was found that the enamel coating was not impervious to attack of lead products, although it did inhibit to some degree the deterioration of the base metals involved. Aluminum coated panels were generally in better shape (after furnace exposure to flue products at 1500° F. for 100 hr.) than the enameled specimens. The No. 25 alloy panel, uncoated, withstood well the attack of flue products, yet in actual service the same material, enamel coated, outlasted the bare metal in the dry tube of a heater. A. H. ALLEN

Steel Pipe Arc Welded Without Back-Up Rings*

DEVELOPMENT of suitable techniques and sound testing procedures has made possible the production of high-quality butt welds in mild steel pipes by the metallic arc welding process, without the use of either temporary or permanent back-

(Continued on p. 142)

*Digest of "Modern Practice in the Welding of Pipes—Background and Present Trends", by E. Fuchs and A. J. P. Tucker, *Transactions of the Institute of Welding*, Vol. 16, June 1953, p. 63-73.

Steel Pipe Arc Welded Without Back-Up Rings

(Continued from p. 140)

up rings. Such pipe is required widely throughout the British chemical industry, and the process is being examined with interest by the oil and steam power industries where welded pipe has conventionally made use of permanent steel backing rings.

Normal metal-arc welding did not give the high quality, homogeneous butt joint demanded, so special procedures were developed, involving five principal factors: (*a*) Use of a small-gage electrode for the root run; (*b*) close control of welding current; (*c*) a large root gap; (*d*) a root face; and (*e*) a weaving motion in laying the root bead, involving continuous movement of the electrode tip from side to side of the weld.

Welds have been made successfully in mild steel pipe with wall thicknesses of $\frac{1}{4}$, $\frac{3}{8}$, and 19/32 in., all with electrodes of 0.192 in. diameter for the root run. The direct current is held to 80 to 85 amp. for the two thinner gages, 85 to 90 amp. for the thicker. Too low a current results in incomplete penetration; too high results in collapse and burning through of the base metal at the point of welding.

A wide root gap is essential to allow the weaving motion of the electrode at the root. It varies from 1/16 to 1/9 in., depending upon wall thickness. The gap must be kept constant, since it tends to close on welding, so it is first tack welded after firm jigging. On 4-in. diameter pipe, for example, $\frac{3}{4}$-in. tack welds are used.

The joints are given a 30 to 35° chamfer and a relatively large root face. A minimum of 1/16 in. and ranging up to $\frac{1}{8}$ in. has been found satisfactory.

Most important feature of the welding operation is the manipulation of the electrode. A continuous arc must be maintained while the electrode is weaved from side to side of the root, with a slight pause at each side long enough to fuse the root face completely. The wide gap of the joint allows the welder to watch this process and to take cognizance of variations in depth of the root face. As the welding proceeds, a half moon is fused out at

(Continued on p. 144)

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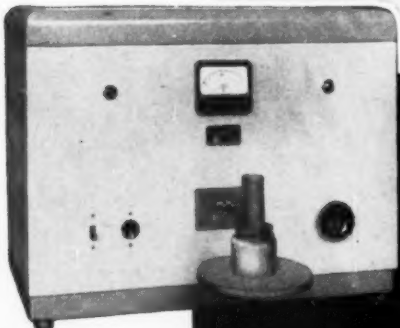

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Steel Pipe Arc Welded Without Back-Up Rings

(Continued from p. 142)

each side of the root just ahead of the deposited weld metal.

For rotated welds, the operator works upward from the 10 o'clock position, the deposited metal running slightly back from the electrode tip to permit observation of the degree of penetration. For positional welds in horizontal pipe, the work starts upward in each direction from the 6 o'clock position.

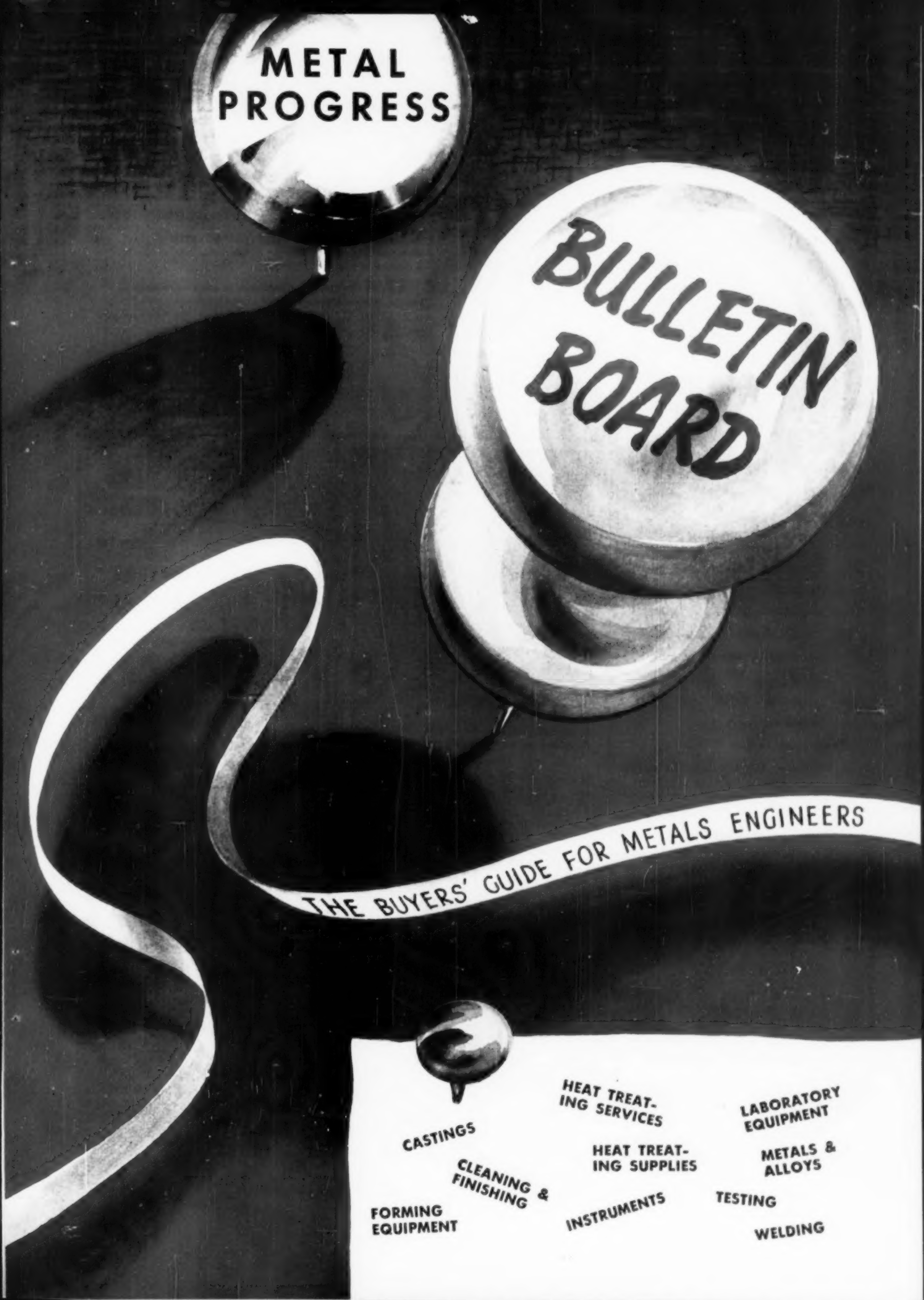
A typical time check on a 10-in. pipe showed a joint completed, with three runs of the electrode, in about 2½ hr., either rolled or positioned. A joint in a 4-in. pipe, also with three runs, was finished in 1 hr.

Control of weld quality is maintained by radiographic examination, periodic tests on welders and occasional removal and examination of completed welds. Careful training of welders is vital, for they must appreciate the need for holding a constant root gap and close control of current for the root bead. Inspection of fit-ups and close supervision of welding the root also have been found important.

Good results have been obtained with similar welding procedure on butt joints in austenitic Cr-Ni steel pipe of 3½-in. o.d. and 3/16-in. wall, as well as on smaller diameters. Tests have been made with three methods, one using shielding of the electrode with argon gas on all passes, a second using shielding only on the root run and the third no shielding. For the shielded arc passes, ⅛-in. diameter wire of 18-8-Ti steel was employed with direct current and the electrode connected negative. Current was 90 amp. for ⅛-in. wall, 140 amp. for 3/16-in. and ¼-in. wall. Joint preparation was similar to results obtained in mild steel pipe.

Bend tests on specimens cut from welds showed that both the metal-arc and the gas-shielded arc gave satisfactory results, control of penetration being easier and more uniform with the gas-shielded arc. Speed also was somewhat higher with the argon-protected arc, and weld cleanliness of a higher order. Advantages of gas shielding showed up even more in tests on welding 3% Cr-Mo steel pipe with 18-8-Ti filler wire.

A. H. ALLEN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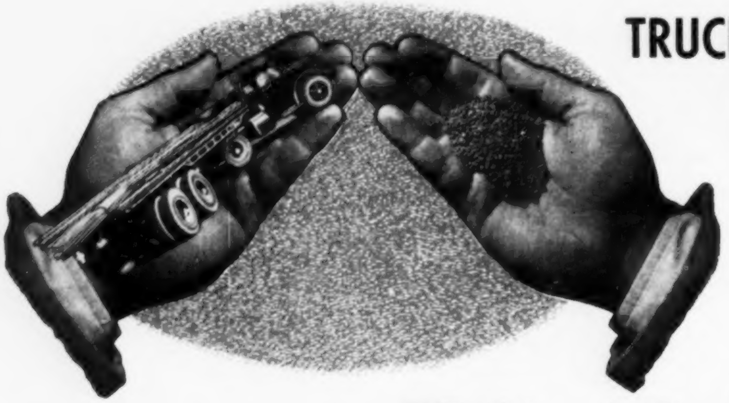

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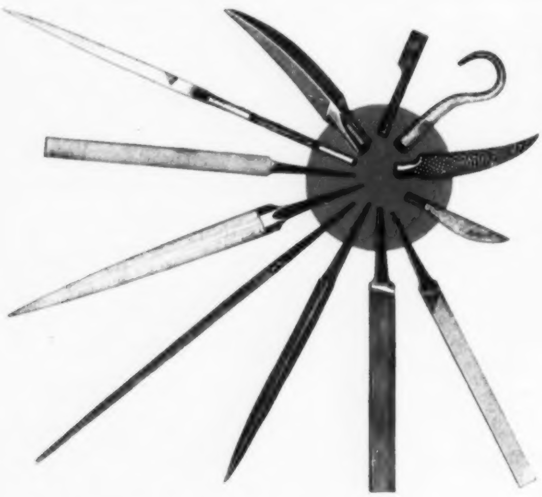

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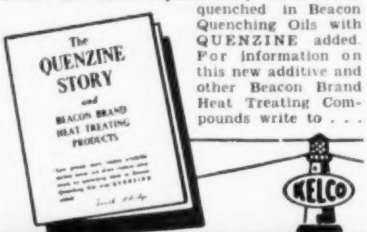

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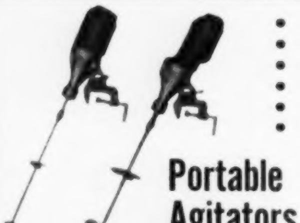

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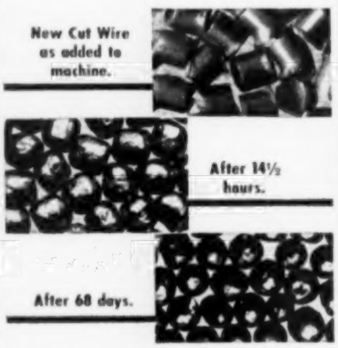

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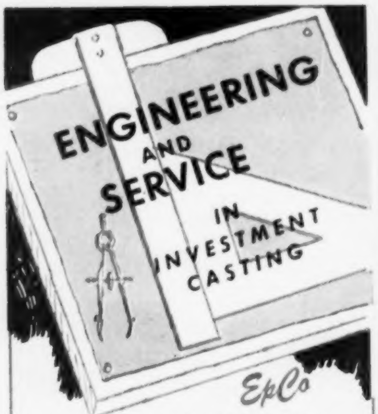

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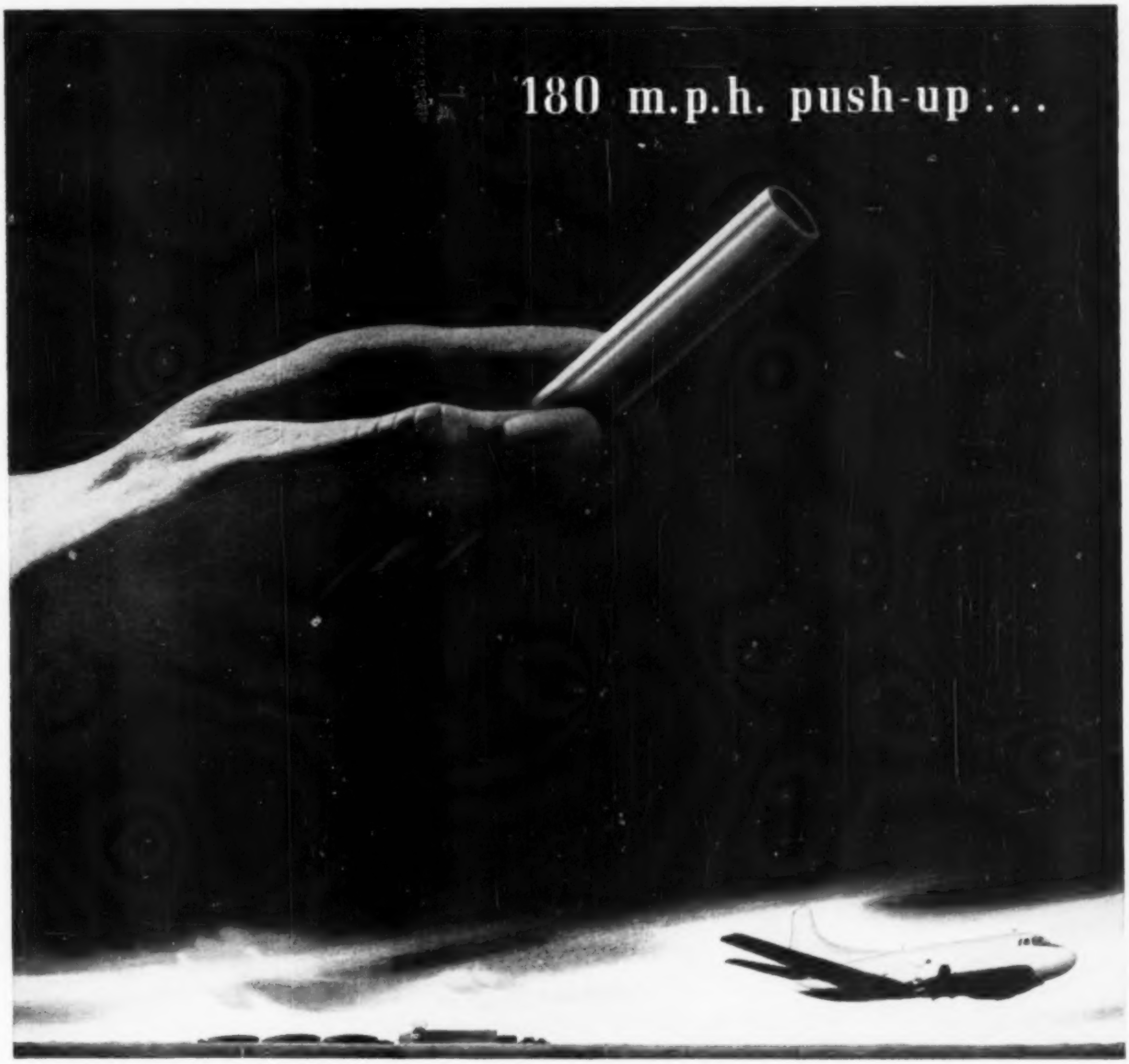

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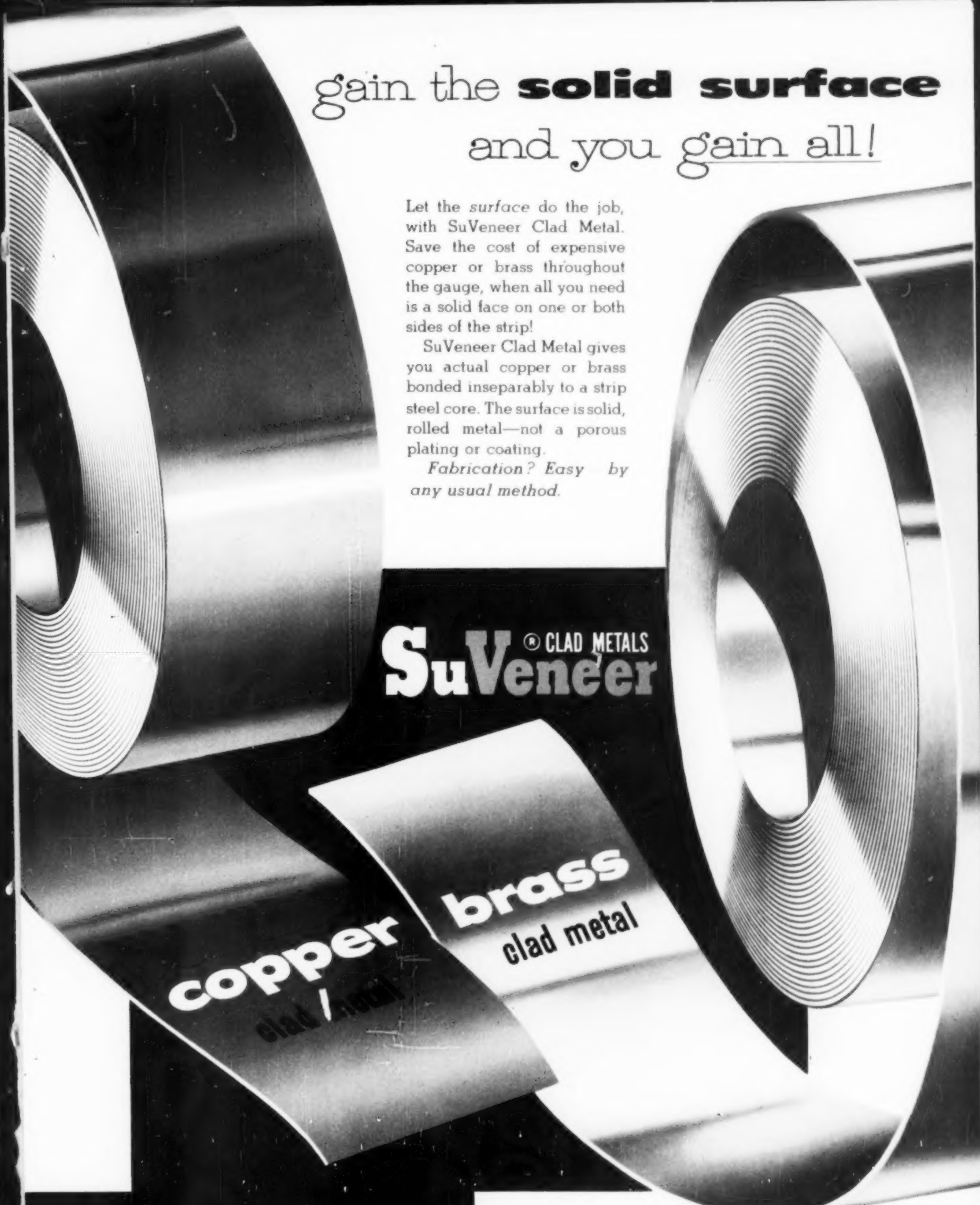
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By SAM McCAULLEY, Silver Division
American Platinum Works, Newark, N.J.

Some Practical Pointers on Silver Alloy Brazing

Silver is a high-priced material and it is not used in brazing alloys because of personal preference or its appearance. It is used because alloys containing silver produce the desired joint most economically. When you buy silver brazing alloys, you are paying for brazing properties—you are buying strong, ductile alloys with low melting temperatures and free flow. These alloys will braze joints at the lowest possible temperatures, they will simplify the joining operation, and they lend themselves to mechanization of the brazing process. The brazing alloy that will give the lowest over-all cost of the joint is usually the alloy with the best flowing properties and lowest brazing temperatures.

About 20 compositions are considered standard today. Many are intended only for specialized applications; a relatively few of the lowest-temperature alloys serve most industrial uses.

These alloys may be divided into two types. One type passes in melting from a solid to a liquid within a few degrees of temperature; the other type passes from a solid to a mushy stage, and progressively becomes more liquid until melting is completed. The first type is generally preferred for brazing of close-fitting joints. The second type is sometimes advantageous if joint fit-ups are poor or inconsistent. With the second type, there may be a tendency for the liquid portion to flow away from the solid when the alloy is in the mushy state, and it is, therefore, advisable to limit the time these alloys are held in the melting range. Melting and flow temperatures are published by most manufacturers as an indication of melting behavior.

Clean metal surfaces are required for brazing, and care in proper preparation of the parts will pay dividends in results. Fluxes are used to maintain the prepared surfaces through the heating cycle. They perform three functions:

1. By covering the work during heating and brazing they prevent oxidation of the surfaces.

2. They may dissolve, reduce or float off surface oxides and tarnish.

3. They reduce the surface tension of the alloy, causing it to flow more freely over the work surfaces and into the joint.

Fluxes consist of combinations of borates and fluorides in a water paste. Fluorine is the active ingredient in all silver brazing fluxes. It is a toxic element and care must be taken to avoid bodily contact with flux or its fumes. The corrosive residue is removed by washing in water.

Figure 1 shows basic joint designs for silver brazing. The lap joint at the top is preferred for most applications. The area of the joint can be increased as desired by increasing the lap, and the parts are readily positioned. Butt and scarf joints are used where space is limited. Preparation and positioning of these joints is difficult and joint area is limited.

In practice, joint designs are more complex, and frequently a combination of butt and lap designs is used. For example, in silver brazing the hub and shaft assembly shown in Fig. 2, there are several possibilities. First, the shaft might simply be butted against the hub, but the limited area of the joint makes this design objectionable. The straight shear joint is preferred but the design can be further improved, as shown at the right of Fig. 2, by a combination

Strong Silver Brazed Joints

of butt and lap, giving more joint area in critically stressed areas. A further improvement can be made by modifying the hub for better distribution of stress in this area.

Proper clearance must be provided between members for proper filling of the joint. This runs from 0.001 to about 0.008 in., with the ideal dimension probably about 0.003 in. A clearance of at least 0.001 in. is necessary for the molten alloy to enter the joint and displace flux and gas inclusions. Above 0.006 or 0.008 in. the alloy will not be held within the joint by capillary attraction.

These clearances must be held at the temperature at which the brazing alloys flow. If the parts of an assembly such as the hub and shaft are of the same metal – steel, for example – the calculation of clearances is elementary. If they are of dissimilar metals, the determination of clearances must take into account the difference in thermal expansion of the parts. For example, if the hub is steel and the shaft is brass, an allowance of 0.010 in. on a 2-in. diameter must be made for the greater expansion of the brass. The coefficient of thermal expansion may be determined from a reference book such as

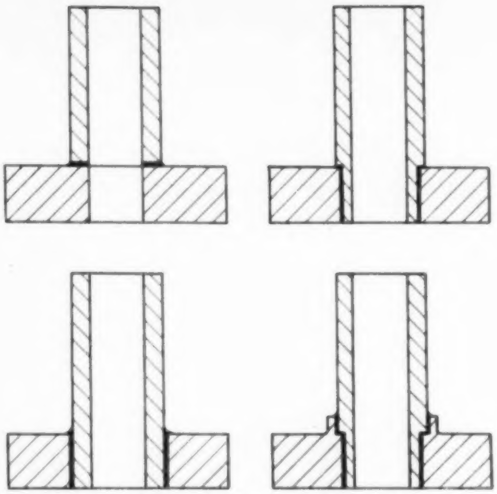
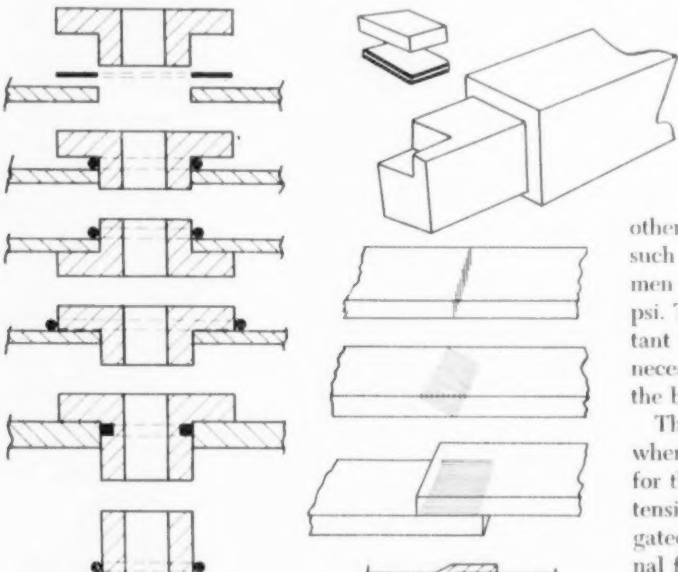


Fig. 2 – Four Types of Joints for a Brazed Hub and Shaft Assembly

"Metals Handbook", 1948 Edition. The normal clearance of 0.003 in. must be provided in addition to this 0.010-in. clearance for thermal expansion.

Fig. 1 – Basic Joint Designs for Silver Brazing. Use of preforms such as washers, rings or other shapes in various positions is an aid to mechanization of the process.



One of the first questions asked by the layman about silver brazing is "How strong is the joint?" This is a difficult question to answer. For example, a tensile specimen made of copper with a brazed joint will stand about 30,000 psi. ultimate load. This approaches the strength of copper itself; nevertheless, the failure does occur at the joint boundary or immediately adjacent to it. If the test were repeated with a specimen of silver alloy, we would find that it failed at about 60,000 psi. This figure represents the ultimate tensile strength of almost all of the silver brazing alloys, although some are slightly stronger than others. With a stronger, harder metal, such as stainless steel, the same specimen would withstand perhaps 120,000 psi. Thus, the base metal has an important influence, and joint strength is not necessarily limited by the strength of the brazing alloy.

The behavior of a tensile specimen when deformed may explain the reason for this to some extent. Under load the tensile specimen becomes slightly elongated and somewhat narrower. If external forces are placed on this specimen to restrain its deformation, its ultimate strength will be affected. This is essen-

(*Continued on p. 164*)

tially what happens to the silver alloy in a brazed joint. The rigidity of the base metal prevents the thin layer of brazing alloy from deforming according to its natural characteristics, and this, in effect, increases its load-carrying ability. Conversely, with a softer, weaker metal, deformation will result in lower strength at the joint.

The advantage of small joint clearance for high strength is therefore readily appreciated; the base metal is able to exert its influence on the joint only if the alloy layer is thin.

For best strength characteristics, stress concentrations should be avoided in parts design; service tests on sample assemblies will provide helpful design data. In the widely diversified applications of silver brazing all methods of heating may be used. Whatever the heating process, the main requirement is to bring the two members of the joint quickly, evenly and simultaneously to the brazing temperature. This demands considerable skill in torch brazing, since the operator must know the heat requirements of various metals and be able to estimate temperature during heating.

The use of preformed rings or other forms preplaced about the joint is recommended wherever feasible, and has permitted mechanization of many brazing operations. Even in manual torch brazing, the use of a preform eliminates one of the human-element factors.

Wherever possible, the alloy should be placed so that it will flow actively into the joint so as to give better alloying with the surface and reduce the chance for flux and gas inclusions. If the alloy can be fed from one edge through to the opposite edge of the joint, the operator will have some indication of how the joint is being filled with alloy. It may also be possible to locate the alloy within the joint so that it will flow out until visible at the boundaries. Such a practice is often used to join electrical busbars.

The final joint should have smooth, natural fillets. Fillets which are built up after the fashion of a weld may be useful in some applications, but again may be merely a veneer over an empty joint. When developing a new procedure, sample parts should be cut open and the joint inspected; the process can then be altered to obtain best results.

Nitrogen in Cast Iron*

NITROGEN is soluble in pure iron up to about 0.04% at 1550° C. (2820° F.). Carbon and nickel decrease this solubility limit; chromium, vanadium and manganese increase it, and the maximum solubility of nitrogen is reached at 1% silicon.

The British Cast Iron Research Association studied the effect of nitrogen upon a series of cast irons of different types. These included both hypo-eutectic and hypereutectic gray irons, a white cast iron which was deemed appropriate for the manufacture of malleable castings—although by American standards it was much lower in silicon (about 0.50%) and much higher in carbon (over 3%)—and nodular cast iron.

Their irons were made in oil-fired furnaces, the nitrogen additions being found to be best made from sodium ferrocyanide plus an equal amount of anhydrous sodium carbonate. Calcium cyanamide plus an equal weight of sodium carbonate could also be used, as well as sodium ferrocyanide alone. Calcium cyanamide, without the fluxing addition, was not so efficient. Additions of 2½ oz. of sodium ferrocyanide plus an equal weight of sodium carbonate to 45 lb. of metal, produced a nitrogen content of 170 parts per million.

When rather considerable amounts of ferrocyanide are used, the molten iron can dissolve sufficient nitrogen to cause gas evolution and blowholes on cooling. This occurred in the region of 335 parts per million.

The effect of nitrogen additions on all the cast irons seems to be the stabilization of the iron carbides. With the hypo-eutectoid cast irons, represented by two melts, the best properties occurred at about 200 or 225 parts per million of nitrogen. The chill of hypo-eutectoid gray iron increases markedly with increasing nitrogen content. With the hypereutectoid, the best properties occurred at 175 parts per million.

During remelting, cast irons lose much of the nitrogen obtained from ferrocyanide, but, as might be ex-

(Continued on p. 170)

*Digest of "Some Effects of Nitrogen in Cast Iron", by J. V. Dawson, L. W. L. Smith and B. B. Bach, *Journal of Research and Development* of the British Cast Iron Research Association, Vol. 4, June 1953, p. 540-552.

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Nitrogen in Cast Iron

(Continued from p. 168)

pected, can be again nitrided by the fluxing treatment.

The graphitizing rate of the single heat made to simulate malleable practice was quite markedly decreased with increasing nitrogen content. This was true both of the destruction of massive carbides and of the destruction of pearlite. Fast heating in the graphitizing cycle produced relatively few nodules but all of which were large. On slow heating, as was expected, the number of nodules increased, as did the graphitizing rate. However, nodules of large size persisted with the higher nitrogen contents.

Three melts were made to which aluminum was added to counteract the effect of nitrogen. The effects did not seem to have been very consistent but did indicate a favorable effect on the part of the aluminum. The only important effect of the nitrogen on nodular cast irons seems to be the retention of somewhat more pearlite. It is reported that commercial cast irons show nitrogen to range from 20 to 150 parts per million.

In the words of the authors, "The results obtained confirm the carbide stabilizing effect of nitrogen already noted in carbon steels. The effect of aluminum in neutralizing the effects of nitrogen has also been confirmed. The effect of nitrogen on embrittlement, if any, has not yet been investigated. In the case of nodular cast iron, the only increase in strength due to the presence of nitrogen is that which arises from an increase in amount of pearlite in the as-cast condition." H. A. SCHWARTZ

Fundamental Research

(Continued from p. 100)

increased scientific attention to the general fields of electrode kinetics and of metal surfaces.

"As an illustration of the first field – electrode kinetics – we are in dire need of accurate anodic and cathodic polarization data for all metals and alloys in a variety of environments. Through such information, we can attain a better understanding of galvanic coupling, incidence of pitting, why metals are passive in some en-

(Continued on p. 172)

Fundamental Research

(Starts on p. 100)

vironments and not in others, and the factors that influence corrosion rates. Precise cathodic data are now available for very few metals—perhaps only platinum and mercury. Similarly, there is a discouraging paucity of precise anodic data. Information of this kind, even though now missing for aqueous solutions, must eventually also include fused salts and organic electrolytes at various temperatures and pressures, and under conditions of low and high velocities.

"As an illustration of the second field – fundamental studies of metal surfaces – information is needed on the effect of lattice imperfections on the nature of chemical attack and its rate as affected by the environment, on rates of adsorption of gases, and initial reaction rates resulting in reaction-product films. Data in this category are essential to our understanding of stress-corrosion cracking, corrosion fatigue and fretting corrosion. We should, furthermore, know more about the relations between types of bonding and electron configuration in metal systems to adsorbed films, reaction-product layers and kinetics of metal reaction generally. Surface studies should include the nature of bonding between metal and films of reaction product, and the detailed structure of the metal-nonmetal interface. Our understanding would thereby be improved of passivity and of factors affecting spalling of protecting layers, as well as of the variables entering the adherence of paints to phosphate coated metals.

"This list is far from complete, and the fundamental problems that bear on corrosion reactions are much broader than is implied by the two fields named above. Nevertheless, I believe that any systematic attempt to focus greater scientific attention on these fields would inevitably result in impressive advances of far-reaching importance to those concerned with corrosion problems – which means practically everybody."

Obviously these are not simple problems. The time required for their full solution cannot be encompassed in a five-year plan. The number of researchers who have the required scientific perspective is small when viewed against the background of these two extensive fields of study.

An obvious corollary is that we need more research workers who are competent in both physical chemistry and metallurgy.

In addition there is a third type of problem which one might classify as a problem in industrial management or national conservation or, if you like, a problem in planning. The Editor has already stated this problem but it bears repeating. Simply this:

Our ignorance is costing us billions per year. Our efforts to combat corrosion in our present partially blindfolded state are costing us millions. Our actual fundamental research on underlying problems is costing us thousands.

How can these figures be brought more nearly into balance? How can our present centers of research on corrosion, which are actually making a start in the direction of fundamentals, be strengthened so that the start will be accelerated from a crawl to at least a walk?

Edisonian Research

(Continued from p. 100)

expected to provide more lasting, even if more diffuse, enlightment.

The overpowering thing that makes it unlikely that the flash-of-genius sort of result will solve many of our practical problems is that what happens in corrosion is determined by so many environmental factors. Some of these can hardly be defined in fundamental terms (let alone controlled, in many instances) and rarely remain constant. Thus, the existence of fundamental information will not, of itself, provide the solution to the practical problems. Its value will be in guiding the selection of conditions for supplementary empirical tests, the choice and improvement of materials worthy of testing, and the interpretation and application of test results.

The attention that has been given fundamental research in this field is much greater than the words of the Critical Point imply and its suggestion that a start remains to be made is not warranted. The answers now available to the questions posed as examples are more than superficial. The real causes of the reactions involved are no more obscure than those of other chemical or electrochemical processes. They involve energy relationships between metals

(Continued on p. 174)

Edisonian Research

(*Starts on p. 100*)

and their corrosion products. The processes of refining metals from their ores leave them in a state where corrosion reactions are spontaneous. What we need to discover is not why most of these reactions occur, but why they do not proceed even more rapidly than they usually do. While it is obvious that we need to know more about rates of such reactions, the practically infinite number of combinations of metallurgical and environmental factors that may be encountered in the general use of metals and alloys in corrosive services is not likely to yield to integral solutions by "flash-of-genius."

It seems likely that we shall continue to have to depend for immediate guidance on empirical tests which we hope will get better and better as we increase our store of fundamental knowledge. Perhaps one can be optimistic enough to hope that we can abandon empirical tests in solving practical corrosion problems as quickly as our contemporaries in another field substitute calculations from fundamental data for the results of empirical mechanical tests – for example, impact tests – in appraising the abilities of different materials to resist the complex physical forces they may encounter in use.

Endurance of Gas Turbine Blades *

SERVICE of high-temperature metals as blades in a gas turbine involves many unique combinations of temperature and stress. Failure in service is to be avoided by all means, but only as accurate data are available on life expectancy under operating conditions can the design be economic and efficient. Hence the importance of such work as has been done at Bristol Aeroplane Co.'s engine division in England, described in the paper under review.

Fatigue tests were made at room and elevated temperatures (500, 600, 700 and 800° C. or 930 to 1475° F.) on five blade materials: "Nimonic 80" rolled bar (21 Cr,

(*Continued on p. 176*)

*Digest of "Fatigue Tests at Elevated Temperatures", by P. H. Frith; *Journal* of the (British) Iron & Steel Institute, 1951, p. 175-81.

Endurance of Gas Turbine Blades

(Continued from p. 174)

3.7 Fe, 2.4 Ti, 0.46 Al, rest Ni)

"Improved Nimonic 80" rolled bar (19 Cr, 0.7 Fe, 2.2 Ti, 0.52 Al, remainder Ni)

"G 32" rolled bar (19 Cr, 15 Fe, 13 Ni, 1.8 Mo, 0.4 W, 1.7 Cb, 2.6 V, 0.30 C, remainder Co)

"Nimonic 80," remelted and cast (approximately as quoted above)

"G18B," remelted and cast (14 Cr, 1 Si, 13.5 Ni, 10 Co, 3.6 Cb, 1.9 W, 1.7 Mo, remainder Fe)

The data presented in this paper, besides providing basic material properties, enabled a comparison to be made of wrought Nimonic 80 to remelted and cast Nimonic 80 having the same heat treatment, and also the effect to be determined of static tensile and static bending loads when added to reversed bending loads. In addition, a few fatigue data were presented for actual turbine blades of Nimonic 80 at 700° C. (1290° F.) prepared by three methods of fabrication.

Endurance limits at room temperature and 500° C. (930° F.) were practically identical for "Improved Nimonic 80" bar. The respective figures are ± 53,700 and ± 51,300 psi. on the basis of 10^7 cycles requiring 83 hr. of testing. (It is not unusual for fatigue properties to be the same up to 500° C. for high-temperature alloys.) At 700 and 800° C. the endurance limits were reduced approximately 22 and 50% respectively. The G32 material (cobalt base) appeared considerably better than the other alloys at its only test temperature, 700° C. (1290° F.). Endurance limits at this temperature were as follows:

Nimonic 80 bar	43,200 psi.
Improved Nimonic 80 bar	46,000
Remelted Nimonic 80	26,200
Remelted G 18 B	19,500
G32B	55,000

Testpieces used at elevated temperatures were bored axially ⅜ in.; the center portion was necked on its exterior in a 1.5-in. radius arc so that the wall thickness at the center of the specimen was 0.0625 in.

An interesting comparison could be made between the Nimonic 80 rolled bars and the remelted and

(Continued on p. 178)

Endurance of Gas Turbine Blades

(Continued from p. 176)

cast. Although having approximately the same composition and identical heat treatment, the casting had only about two thirds the endurance limit of the rolled bar. Its ultimate strength and yield strength was equally poor. (It is unfortunate that photomicrographs and creep-rupture data weren't included to complete the comparison. This would have been an added contribution to the present-day argument about forged versus cast materials for gas turbine blades.)

When vibratory reversed bending stresses were superimposed on a 13,500-psi. *static tensile* stress (a stress condition similar to that in gas turbine blades while operating), the endurance limits for the Improved Nimonic 80 bar were reduced approximately 25% at 700° C. (1290° F.). The Improved Nimonic 80 bar appeared to have 5 to 16% better endurance at 83 and 100 hr. respectively than Nimonic 80 bar at 600° C. (1110° F.) under these combined stress conditions. This difference was not apparent when tested under simple reversed bending.

The total of combined static and dynamic tensile stresses was, of course, applied for only a small percentage of the testing time; however, for the Nimonic 80 bar (with a 13,500-psi. static tensile load) it appeared that fatigue was the predominant condition affecting failure at 600 and 700° C. (1110 and 1290° F.), while creep was probably the predominant condition at 800° C. (1470° F.). This static tensile load approaches the rupture strength of the alloy at that temperature.

With the remelted and cast G18B bar, the endurance limits at 700° C. (1290° F.) were not appreciably affected by superimposing reversed bending on the 13,500-psi. static tensile stress. The G32 alloy and remelted and cast Nimonic 80 were not evaluated under these conditions.

For Nimonic 80 bar, reversed bending stresses were superimposed also on a *static bending* stress of 13,500 psi., but the endurance limits at 700 and 800° C. were practically unaffected.

Actual turbine blades of Nimonic 80 fabricated by three methods were also run in a fatigue machine at 700° C. (1290° F.) under reversed bending. The results are shown at the top of the page.

Method of Manufacture	Stress	Cycles	
Forged close to size and honed	±38,000	1.9×10^6	(B)
Machined from forged slug	±45,000	20.0×10^6	(UB)
	±38,200	49.3×10^6	(UB)
	±36,000	33.8×10^6	(UB)
Precision-cast and honed	±24,800	50.0×10^6	(UB)
	±22,600	31.5×10^6	(B)
	±20,600	66.1×10^6	(UB)

B = Broken UB = Unbroken

The data indicated that blades exhibit fatigue properties similar to laboratory-tested bar stock only when machined from a forged slug. (Data such as these are no doubt a basis for the British preference for forming blades of Nimonic alloy by machining from rough forgings rather than by precision forging.)

G. M. Ault

Tool Steel Topics

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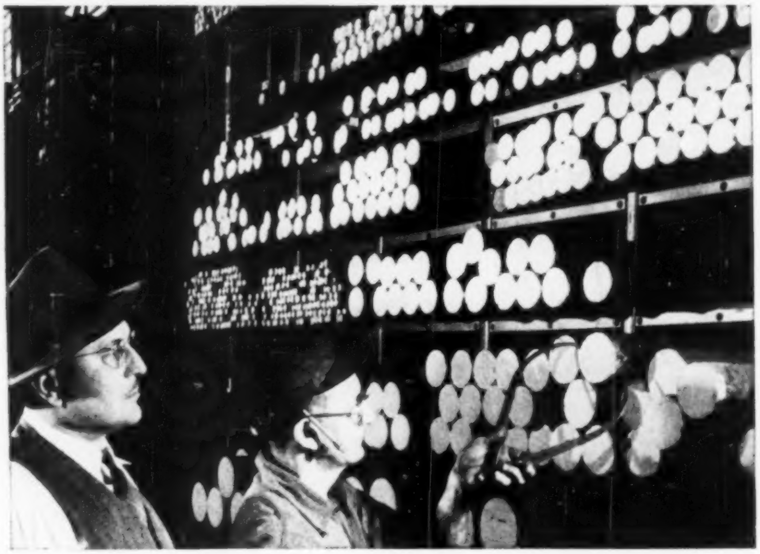

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BETHLEHEM TOOL STEEL ENGINEER SAYS:

Don't Use Fresh Water for Quenching Tools

It makes no difference what the source may be — fresh water is simply unsuitable for the quenching of tools. For all fresh water contains dissolved gases, which are released at the surface of the tool when it is quenched. The small gas pockets thus formed can prevent contact between the tool and water, and the resultant ineffective quench causes soft spots. These soft spots are likely points for cracks to occur in the tool.

A good way to avoid this trouble is to quench in water which has been boiled to remove the dissolved gases. Suppose the water cannot be boiled? Then expel the gases by quenching a large amount of hot "dummy" material. Even better would be a 10 pct brine solution, made up using degassed water.

New Booklet on Bearcat Tool Steel

We recently issued an attractive 2-color booklet on Bearcat Tool Steel — the versatile general-purpose steel that is so well suited for applications involving high shock-resistance. The 8-page illustrated booklet contains a wealth of information about Bearcat — goes into considerable detail about its hot-work and easy machining properties.

Bearcat is a super steel in every respect. It is air-hardening, thus minimizing quenching hazards, and it has good resistance to distortion during heat-treatment.

OTHER ADVANTAGES OF BEARCAT

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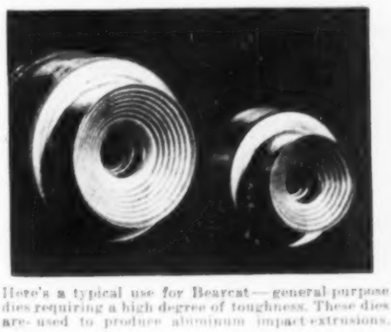
1. Deep hardening
2. Easy machining (Brinell 197 max)
3. Low distortion in heat-treatment
4. Good hot-work properties
5. Easily carburized for long wear

TYPICAL ANALYSIS

C	Mn	Si	Cr	Mo
.50	.70	.25	3.25	1.40

Bearcat is especially recommended for both hot- and cold-shock applications such as rivet sets, chisels, punches, hot headers, and gripper dies. It is also ideal for short-run dies used in cold-forming, blanking, and bending, as well as for engraving dies, die-casting dies, and master hobs. It has many other uses, too.

It will be worth your while to look into Bearcat. Why not talk it over with your Bethlehem tool steel distributor? And of course you'll want to read the new booklet on Bearcat. Write to the Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. Ask for Booklet 341.



Here's a typical use for Bearcat — general purpose dies requiring a high degree of toughness. These dies are used to produce aluminum impact-extrusions.

Ore Reduction in Low-Shaft Blast Furnace*

Since the end of the last war, there has been a trend to improve the blast furnace process, especially to develop methods in which high-quality coke is unnecessary. D. Durrer expressed the opinion, in his talk at Instituto del Hierro y del Acero in Madrid, November 1948, that present methods of iron smelting call for unnecessarily high quality of raw materials, and that methods capable of using lower grade ores and fuel should be developed. In this paper a method is described which meets these requirements developed in 1950 and the first part of 1951 at the Klockner-Humboldt-Deutz Corp. in Koln-Kalk, Germany.

Because of its advantages, this method may be of considerable interest in all countries which produce iron and steel. Lower grade coals can be used as well as ores which usually are avoided by blast furnace operators. Also, lower investment costs result because the byproduct coke plant can be omitted. For countries having iron deposits but no suitable coking coals, this method may be of greatest importance.

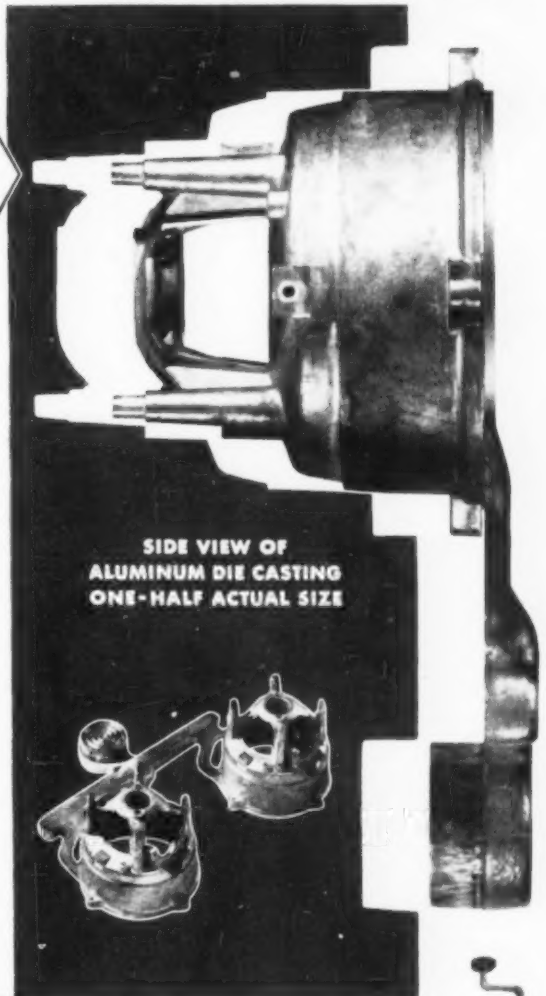
The first experiments at Humboldt were carried out by L. Weber as a two-step process. First step was coking of the coal and second step was reduction of iron ore. Later Otto Diettrick united both processes in one operation. This makes it possible to work with fine-grained material. The ore and non-coking coal are ground, mixed with binders, and then briquetted. In the low-shaft blast furnace, coking takes place in the top zone and iron reduction and melting in the hearth zone. The briquettes weigh approximately 3 oz. The shape of the briquette influences the reduction process and in this way it is possible to compensate to a certain degree for differences in ore properties. Although the reduction zone is only about 10 in. deep, the briquettes must have sufficient strength. This strength requirement, however, is lower than for the coke

(*Continued on p. 182*)

*Digest of "New Experiences With Iron Ore Reduction in Low-Shaft Blast Furnace", by Erick Killing, *Stahl und Eisen*, Vol. 72, July 31, 1953, p. 925-928.

IT TOOK A LESTER

TO FILL THESE SUSPENSION LUGS FOR ELECTROLUX IN CANADA



The design of this aluminum motor housing, with its four long suspension lugs, cast in blind holes, demanded the utmost in shot speed control and high final squeeze. Several other die casters attempted it and failed. But at Electrolux (Canada) Ltd., on a Lester-Phoenix HHP-3X-S die casting machine equipped with a Pre-Fill, they succeeded. These lugs were formerly steel inserts screwed into the casting. *By eliminating the inserts, Electrolux saved 12c per casting!*

This is part of the background to the success story at Electrolux where, as Mr. Edward Gaudry of the Engineering Department, says, "...We have realized a saving of approximately 30% to 40% over our previous cost of die castings, and this was accomplished... with green operators who had to be trained on the job.

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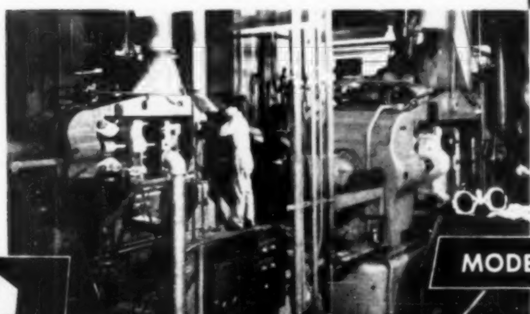

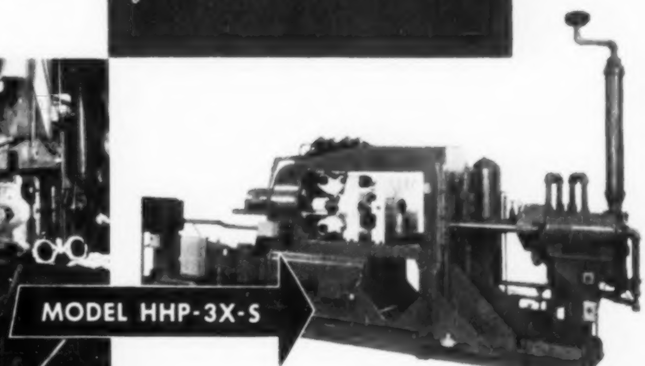

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Ore Reduction in Low-Shaft Blast Furnace

(Continued from p. 180)

generally used in standard high-shaft blast furnaces.

Compared with the standard blast furnace, such auxiliaries as coke plant, compressors and stones are largely omitted in the low-shaft furnace. Replacing these are a crushing and briquette plant, smaller exhausters, and only one recuperator. The gas must be cleaned more completely because it contains valuable tar needed as a briquette binder.

After several experiments, Diettrick designed a low-shaft furnace capable of a daily production of 60 to 80 tons of pig iron from good ore and coal. The quality requirements for raw materials and briquettes are as follows: The ore may be in any physical condition or of any chemical composition. Crumbling ores are advantageous for the briquetting. Fine ore is not ground, and as much as 30% of small lumps up to ¼ in. can be tolerated in the briquettes. No trouble is encountered with ores containing alkalis or sulphur. The use of ore concentrates decreases the consumption of slag and fuel. The reducibility of the ore is not as critical as in the standard blast process because the ore for low-shaft furnaces is of finer grain and is intimately mixed with carbon in the briquettes. Special advantages are evident in the smaller grain size for ores such as magnetite which are hard to reduce in lump form in a standard furnace. The quality requirements for coal are just as wide as for the ores. Coal of any kind, lignite, or coke dust may be mixed with the ground ore and briquetted.

The basicity of the slag is controlled in the usual way by additions of new lime, or the lime may be mixed with the ore, coal and binder for the briquettes. Tar pitch, asphalt, and sulphite tar have been used as binder materials.

Dried ore, coal and lime, all of which are ground to less than ⅛ in. diameter, are mixed with 6% tar or other binders and are formed into briquettes under a pressure of around 3500 psi. Small briquettes are best.

The briquettes are charged cold in the furnace where they meet a gas

(Continued on p. 184)

H. J.
Here's a really fantastic letter!
P.W.

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June 16, 1952

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Attention: Mr. P. E. Watts

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We were using a tapping compound with precision ground taps in order to hold to close tolerances. We did not consider tap breakage excessive but the removal of broken taps was sometimes rather expensive. He recommended we use "Chillo 10Z". Then came the surprise of our lives! With Chillo 10Z we have gone to commercial ground taps (a 300% savings) and can still hold our same tolerances, with a sharper thread, increasing tap life a minimum of 20% plus eliminating expensive removal of broken taps!

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Yours very truly,
BANNER TOOL COMPANY

S F Olesak

S. F. OLESAK

SFO:sd

Ore Reduction in Low-Shaft Blast Furnace

(Continued from p. 182)

at temperature of 450 to 650° F. This gas contains approximately 3% CO_2, 30% CO, 5% CH_4 and 7% H_2. Coking begins when they are heated to 1100° F., and the tar given off at this temperature is condensed in the gas cleaners and used as binder. (Low volatile coals will not yield enough tar for this purpose.) The burned and coked briquettes must be strong enough to carry the burden until they reach the tuyeres.

Experiments were run with ores varying from 17 to 67% Fe, 0.15 to 6.65% MnO, 4.3 to 22.25% SiO_2, 9 to 30.5% CeO, 0.33 to 16% Al_2O_3, 0.1 to 2.34% MgO, 0.9 to 2.06% P, 0.1 to 3.3% SO_3, 0.1 to 5.17% $Na_2O + K_2O$ and 0.1 to 3.9% TiO_2. The coals varied from 5 to 23% ash and 4 to 35% volatile matter.

The blast had a pressure of 48 in. of water; 1765 to 2118 cu. ft. per min. was used. When 30 tons of pig iron was made per day the air was preheated in recuperators to a range of 30 to 800° F. Some experiments were carried out in a small water-jacketed furnace having a hearth of 6 sq. ft., but most of the study was made on a furnace with a hearth area of 18 sq. ft. (hearth dimensions about 3x6 ft. at tuyere zone). To avoid trouble, all experiments were carried out with excess coal and usually very hot iron was produced.

The heat supplied is essentially used for vaporization of water, and calcination of carbon dioxide, reduction of ore, heating and melting of the iron and slag, heating the effluent gas and for radiation losses. A greater amount of heat is absorbed during the reduction in the low-shaft furnace because iron oxide is reduced by carbon instead of by CO gas, as in the conventional furnace. The variation in heat balance between direct and indirect reduction is given by

$$Fe_2O_3 + 3C \rightarrow 2FE + 3CO = -116.0 \text{ kg-cal.}$$

$$Fe_2O_3 + 3CO \rightarrow 2FE + 3CO_2 = 7.6 \text{ kg-cal.}$$

In some instances, significant heat losses occurred through the hotter and richer gases. These losses can easily be kept at the same level as in the standard blast furnace because

(Continued on p. 186)

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Ore Reduction in Low-Shaft Blast Furnace

(Continued from p. 184)

the top-gas temperature may be controlled. Losses through conduction and radiation were above the normal 10% in the small experimental furnace. The cold blast also was unfavorable. Controlling these factors in a proper manner is said to reduce the fuel consumption to the same fuel-iron proportion as in the high-shaft blast furnace. In addition, all the usual heat losses in the coke plant are saved.

In all the experiments in which sufficient fuel was used, the iron was gas-free, quiet, and very hot. The pig iron contained 3.4 to 4% C with 0.01 to 0.38% chemically combined carbon, 1.6 to 4.2% Si, 0.2 to 0.9% Mn and about 0.025% S. The reduction of silicon is remarkable in the small furnace and may be kept lower in larger units. The first goal to produce a good foundry pig was successfully reached. The manganese reduction was 40 to 60% and reduction of phosphorus also was normal. The low amount of combined carbon is remarkable as well as the desulphurization. In some of the experiments in the small (6 sq.ft.) furnace, the sulphur content was well within specifications even though three times the permitted amount was present.

The slag was kept very basic with a CaO-to-SiO_2 ratio of 1.2 to 1.6. The slag was molten and free flowing. The slag composition varied between 0.6 to 3.6% FeO, 39.6 to 51.2% CaO, 28 to 38.9% SiO_2, 8.4 to 19.9% Al_2O_3, 0.8 to 3.4% MgO, 0.1 to 1.2% MnO and 0.6 to 2.9% S. The slag volume was 1763 to 2865 lb. per ton of iron, depending on the quality of ore and coal used.

The top-gas temperature varied between 500 and 800° F. The quantity was calculated as 88,250 to 141,200 cu.ft. per ton of coal. Gas composition varied from 2.2 to 3.5% CO_2, 29 to 32.8% CO, 2 to 7.5% CH_4, 6 to 8.5% H_2 and 55 to 58.5% N_2, the lower heating value being 144 to 161 Btu. per cu.ft.

The economy depends very much on location and raw materials available. According to calculations based on the experimental results, it seems that the fuel costs will be equal to or

(Continued on p. 188)

Ore Reduction in Low-Shaft Blast Furnace

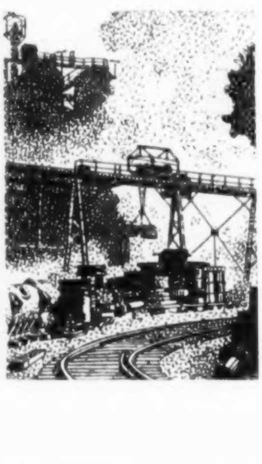
(Continued from p. 186)

perhaps slightly more favorable in the new process if the same coals are used. The cost of sintering, which is necessary for many ores, may be substituted for slightly lower costs in the briquette plant. The investment for new plants of the same capacity is undoubtedly smaller.

The raw material expenses, however, are different. Blast furnace coke is priced at 80 to 120 Reichsmark (RM) per ton, whereas coal may be set at 50 RM per ton On this item alone pig iron can be produced at 30 to 70 RM per ton cheaper. If transportation must be added to higher quality products because it is unavailable nearby, the difference becomes much greater. With the price for foundry pig at 200 to 220 RM per ton compared to imported pig at 400 RM per ton, a saving of up to 200 RM per ton is possible. In the areas where byproduct coke is produced this advantage is very much diminished, but even so it is possible to reduce costs under these conditions. The method seems to be favorable especially where raw materials of high alkali, sulphur, and high clay content are encountered.

The method has another significant advantage because it can be run economically in smaller units of 100 tons furnace capacity to local resources or markets. (The investment is arbitrarily proportional to production and the huge investment required for a standard high-shaft furnace may be avoided.) The low-shaft furnace may be readily started and shut down without damage.

E. C. WRIGHT



Quality Control in the Production of Brass Castings*

THE QUALITY of a casting for processing into sheet, strip, section, rod, tube or wire is determined by its composition, surface condition, internal soundness and structure. If any of these factors are below standard, fabrication is impeded, costs are increased and the product is impaired. Quality is influenced by raw materials, melting, casting, and is discussed in this paper principally under these captions.

RAW MATERIALS

The principal raw materials are virgin metals, temper alloys and scrap. The first are usually of uniform quality and require only sampling and analysis for impurities. Temper alloys such as ferrocopper, phosphor copper and manganese copper require careful checking for impurities. Process scrap requires only rigid segregation by alloys. Purchased scrap must be inspected, sorted when necessary, often sampled and analyzed. Free iron may be removed from swarf by using a belt-type magnetic separator. Iron can be detected in baled scrap by passing the bales through a direct-current coil. Hopelessly mixed scrap is sometimes homogenized by melting and casting into pigs for analysis.

MELTING

Defects that can have their origin wholly or partly in melting include incorrect or variable composition, metallic or nonmetallic impurities and, in some alloys, unsoundness due to gas absorption. Low-frequency furnaces are principally used for melting, although some crucibles and a few are furnaces are in use.

Some loss by volatilization and oxidation is inevitable. It must be compensated and controlled. The order and manner of charging is regulated with regard to rate of solution and oxidation. Zinc is added

(Continued on p. 192)

*Digest of "The Control of Quality in the Production of Brass Ingots and Billets", by Maurice Cook and C. L. M. Cowley, *Journal* of the Institute of Metals, Vol. 81, March 1953, p. 341-50.

Quality Control in the Production of Brass Castings

(Continued from p. 191)

toward the end. A protective cover of charcoal is used, this being fluxed with salt increasingly as the tendency to dross increases with high zinc and fine scrap. With alloys containing silicon and aluminum, the inclusion of oxides in the molten bath must be avoided. With low-frequency melting it is advantageous to use a recording chart indicating the stages of operation; that is, full power, standby, pouring.

It is necessary to avoid contamination from stirring tools and from a succession of unlike alloys. The latter are avoided as far as possible and large wash-out charges used when necessary. Gas absorption is not a hazard with yellow brass, but an oxidation-reduction treatment is used for nickel silver. Samples for analysis are taken from the pouring stream.

Statistically, copper should be determined on each charge, minor constituents on alternate charges, while the castings are held for the analytical report. Impurities are determined spectrographically. Interest in the direct-reading spectrometer is active, with the possibility that the report can be made before pouring.

CASTING

Pouring temperature, molds, mold dressing, rate of pour and method of feeding are determined by metallurgical considerations.

Temperature control should be specific, not left to the eye, and a recording chart bearing a continuous record is preferable to spot checking. A table of pouring temperatures for brasses and nickel silvers is given. The pouring temperature is a compromise between the greatest internal soundness and the best surface. A low temperature favors the former; a high temperature the latter but, for a given alloy, the optimum varies with the size, form and type of mold. The structure of three slabs of 67-33 brass cast at different temperatures is shown.

Cast iron and water-cooled molds are used. The former develop cracks and a scale which retain mold dress-

(Continued on p. 198)

METAL PROGRESS

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Subject Index for Vol. 64

The subject headings used in this index are chosen in accordance with the ASM-SLA Metallurgical Literature Classification, published by the American Society for Metals, 1950

(br) Book Review; (c) Correspondence; (cp) Critical Points; (d) Digest; (ds) Data Sheet; (sr) Short Runs.

Author Index

(br) Book Review; (c) Correspondence; (cp) Critical Points; (d) Digest; (ds) Data Sheet; (sr) Short Runs.

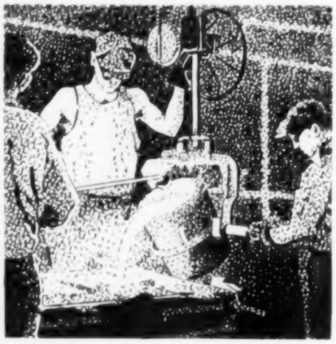
Quality Control in the Production of Brass Castings

(Starts on p. 191)

ing and cause internal unsoundness. The latter, with copper face-plates, are subject to neither of these hazards. For a 1000-lb. casting, 100 gal. of water (at 70° F.) per min. is used in the mold.

Care in design is necessary to insure uniform circulation. The face-plates in Junker-type molds are prone to fatigue failure at the bolt holes.

For most brasses, a mixture of mineral oil and powdered charcoal is an adequate mold dressing. Tallow is added for gilding. For the casting of rolling slabs in cast iron molds, resin is preferred for brass; tallow and charcoal for gilding. Lard oil with black lead is used for nickel silver. Mold dressing is boiled to remove moisture. The correct dressing of a mold is a matter of experience.



For pouring, the mold is vertical. Cast iron tundishes, with suitably spaced and sized holes, permit even distribution and rise of 1 to 1¼ in. per sec. for the metal in the mold. Castings are fed through the tundish, with a ladle or directly. Hot-tops have not been much used for brass. Durville molds are used for aluminum alloys.

Castings are thoroughly inspected for surface condition and soundness when the gate is removed. Aluminum, manganese, silicon as impurities can be detected by the charcteristic golden, reddish, or silvery color of the gate end. D. R. HULL

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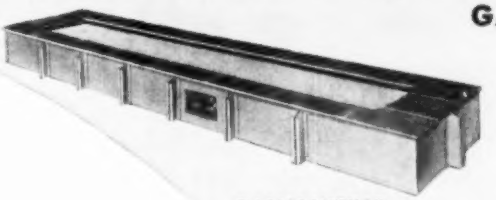

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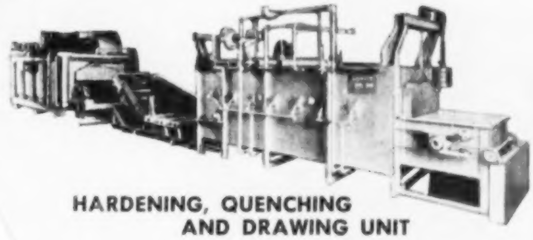

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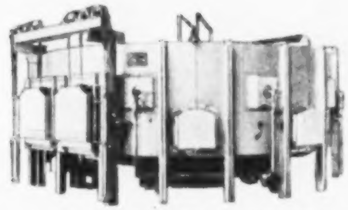

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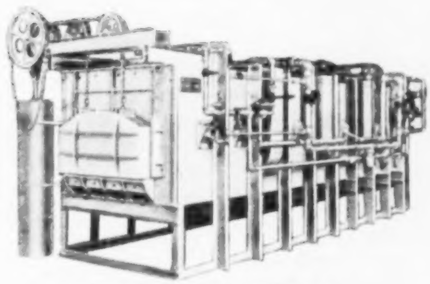

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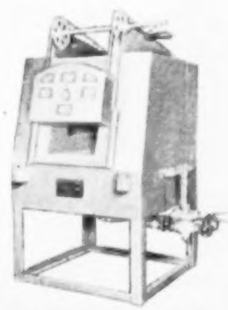

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Theory of Pearlite Growth*

THIS PAPER, awarded first prize in the Birmingham Metallurgical Society Essay Competition, presents the modern theory of pearlite growth, summarizing and correlating observations and theories available in recent literature. The story of pearlite growth is clearly and concisely written, including descriptive material and mathematical analyses. The author shows that the process of growth is fully understood and that experimental results are in close agreement with the theoretical predictions. He also points out that the remaining gaps in theory offer an interesting challenge to metallurgists. Direct evidence shows that pearlite is nucleated by cementite and that nucleation occurs at austenite grain boundaries. The pearlite colony grows sidewise along the austenite grain boundary by nucleation and growth of alternate plates of cementite and ferrite; these plates grow edgewise into the austenite grain. The rate of growth of pearlite is independent of the austenite grain size but does vary with temperature and with austenite carbon content.

Pearlite is made up of a number of contiguous colonies, each colony being composed of substantially flat and parallel plates. Each colony grows outward from a single cementite nucleus. The strains associated with the transformation are presumably sufficient to induce cementite nucleation in the austenite near the pearlite-austenite interface, and to cause a mating colony to form in the neighboring austenite crystal across the grain boundary. Growth within a single colony occurs by two means—edgewise growth, controlled by the diffusion rate of carbon in austenite, and sidewise growth, involving nucleation and growth of alternate platelets of cementite and ferrite.

The diffusion equation is given, relating the velocity of edgewise growth to the diffusion coefficient, the interlamellar spacing, and the carbon concentrations in the austen-

(Continued on p. 202)

*Digest of "The Theory of the Growth of Pearlite", by E. G. Eeles, *Journal* of the Birmingham Metallurgical Society, Vol. 33, March 1953, p. 29-43.

Pearlite Growth

(*Continued from p. 200*)

ite, the cementite and the ferrite. The theoretical value for growth compares very favorably with the experimental value when corrections are made for variations of the diffusion coefficient with carbon content.

It is possible to relate the rate of edgewise growth, the interlamellar spacing, and the temperature. However, the interfacial energies are involved in this analysis and apparently no values are available for these at the present time.

In the sidewise growth, the first platelet of cementite begins to grow at a rate governed by the diffusion rate of carbon. This rate decreases as the carbon is depleted in the nearby austenite, causing a ferrite layer to nucleate adjacent to the cementite plate. The rate of growth of the ferrite plate is rapid at first, but decreases as it grows into the region of austenite where the carbon concentration is greater. The rate of growth continuously decreases as more carbon is transferred to the remaining austenite, and finally a new cementite layer nucleates and the process is again repeated. Like edgewise growth, the rate of sidewise growth is governed by the rate of diffusion of carbon in austenite, but the process is cyclic and involves the formation of new nuclei of cementite and ferrite. Nucleation theory indicates that the interlamellar spacing should not be uniform but should have a statistical distribution about a mean value. This has been checked experimentally and found to be true.

The interlamellar spacing decreases with decreasing temperature because the higher degree of supersaturation of the austenite increases the nucleation rate of cementite, and also because the diffusion coefficient decreases rapidly with decreasing temperature.

The effect of alloying elements is also discussed. The diffusion rate of carbon is not significantly affected by the presence of other elements; consequently, it is presumed that the other alloying elements must also segregate during the formation of pearlite. Also, the rates of nucleation of cementite and ferrite are retarded by alloying elements other than cobalt; hence the rates of growth should be retarded.

E. R. PARKER

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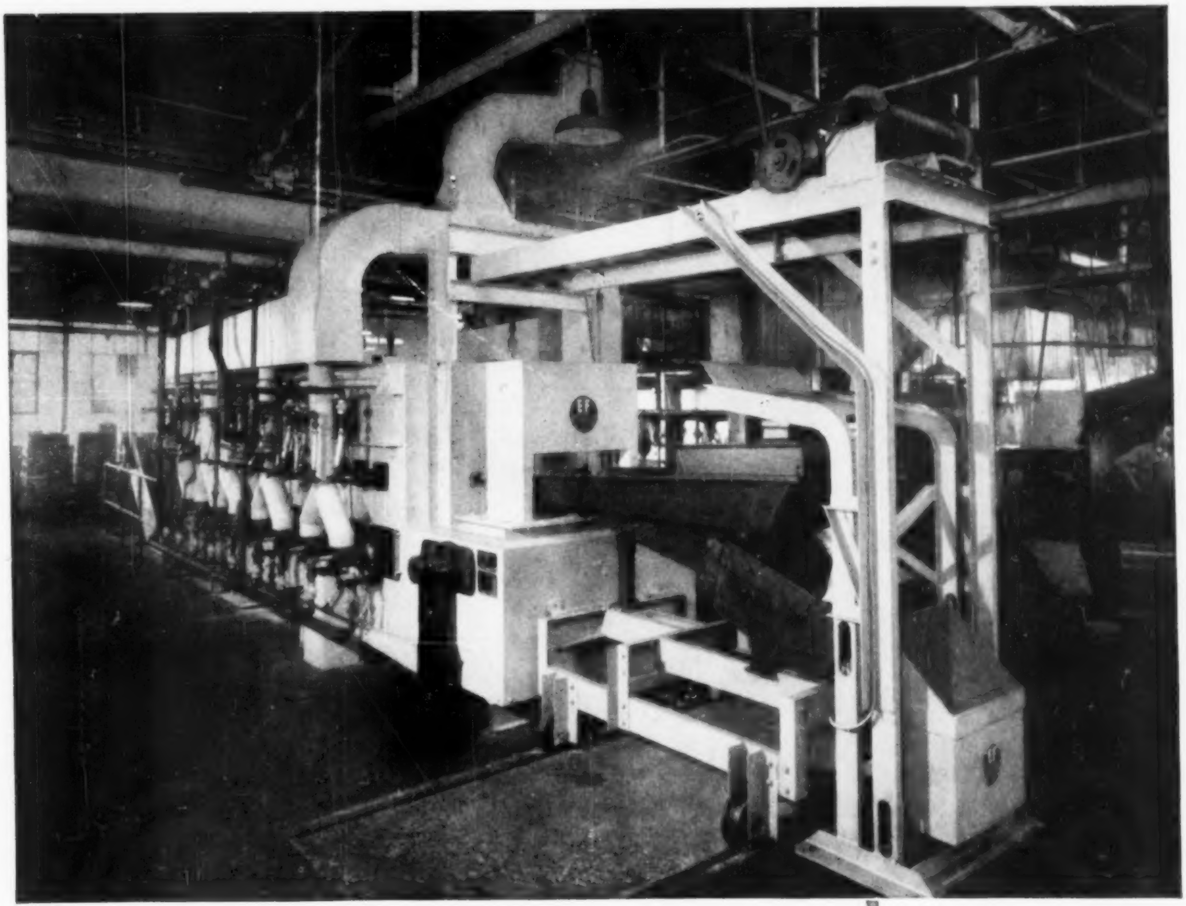

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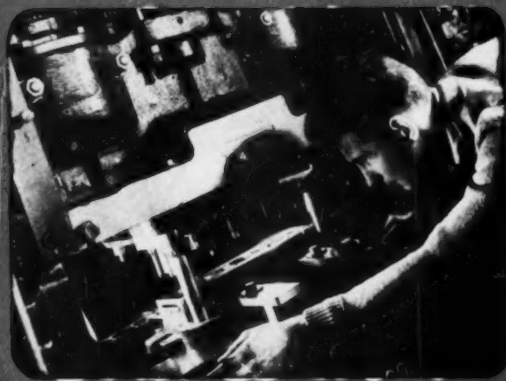

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